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CHEMICAL CONTROL OF ROUGH FISH IN THE RUSSIAN RIVER DRAINAGE, CALIFORNIA[1]

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[1] Submitted for publication September, 1957. A portion of this work was performed by personnel of Dingell-Johnson Project California F-4-D, "Stream and Lake Improvement", supported by Federal Aid to Fish Restoration funds.

INTRODUCTION

The chemical control of fish populations is an important form of fisheries management. Undesirable fishes have been eliminated or at least controlled, and game fish populations have been established or improved. This form of management, although commonly used in lakes and ponds, has not been used to any great extent in streams.

Preliminary fish population sampling in the Russian River drainage showed that rough fish [2] composed almost 100 percent of the population

TABLE 1

Streams in the Russian River Drainage Chemically Treated to Control Rough Fish

Stream	County	Miles treated
Main Russian River		
East Branch to Healdsburg	Sonoma-Mendocino	62
Tributaries		
Russian River, West Branch	Mendocino	18
Forsythe Creek	Mendocino	7
Mill Creek	Mendocino	1
York Creek	Mendocino	1
Russian River, East Branch	Mendocino	16
Bush Creek	Mendocino	3
Mewhinney Creek	Mendocino	2
Ackerman Creek	Mendocino	3
Sulphur Creek	Mendocino	4
Robinson Creek	Mendocino	5
McNab Creek	Mendocino	5
Feliz Creek	Mendocino	8
McDowell Creek	Mendocino	1
Pieta Creek	Mendocino	2
Coleman Creek	Mendocino	1
Cumminsky Creek	Mendocino	4
Big Sulphur Creek	Sonoma	13
Little Sulphur Creek	Sonoma	5
Maacama Creek	Sonoma	11
Briggs Creek	Sonoma	4
Little Briggs Creek	Sonoma	1
Coon Creek	Sonoma	1
Bear Creek	Sonoma	1
Ingalls Creek	Sonoma	1
Redwood Creek	Sonoma	1
Dry Creek	Sonoma	33
Gallaway Creek	Sonoma	4
Cherry Creek	Sonoma	5
Warm Springs Creek	Sonoma	6
Pena Creek	Sonoma	10
Mill Creek	Sonoma	5
Porter Creek	Sonoma	1
Mark West Creek	Sonoma	9
Windsor Creek	Sonoma	2
Laguna de Santa Rosa	Sonoma	6
Santa Rosa Creek	Sonoma	11
Green Valley Creek	Sonoma	10
East Austin Creek	Sonoma	3
Total miles treated		286

Streams are listed from north to south, with the various indentations indicating sequence of tributaries; e.g., Mill Creek is a tributary to Forsythe Creek, which in turn is a tributary to Russian River, West Branch.

[2] For the purposes of this report, the collective term "rough fish" includes all undesirable fishes the presence of which may be detrimental to steelhead and other game fishes.

in certain tributary stream sections. It was believed that if control of these rough fish would reduce predation and competition for food and space, an increase in game fish production and harvest would result.

Preliminary chemical control of rough fish in the Russian River drainage began in 1952 on several tributary test streams and continued in 1953. As more extensive sampling of the drainage was undertaken, it became evident that control should include the large numbers of adult rough fish in the main river. It is through this area that yearling steelhead rainbow trout *(Salmo g. gairdnerii)* pass on their migration to the sea. The project was therefore extended through 1954 to include nearly half the entire river drainage, or about 286 stream miles (Table 1).

The project was directed toward control, rather than eradication, since various sources for future infestation by rough fish would still exist. Primary consideration was given to the tributary streams which serve as nursery grounds for juvenile steelhead.

The evaluation of the project began with immediate follow-up checks of the fishes killed, and will continue for several more years.

DESCRIPTION OF THE RUSSIAN RIVER DRAINAGE

The Russian River originates in the higher portions of the Coast Range in Mendocino County and flows southward through Sonoma County, where it turns rather abruptly west and flows into the Pacific Ocean at Jenner, about 57 miles north of San Francisco (Figure 1). The river system has a total of some 576 miles of stream, of which the main river makes up 108 miles. It drains an area of about 1,485 square miles.

Since 1908, water has been diverted through a tunnel from Van Arsdale Reservoir (Cape Horn Dam) on the Eel River, Mendocino County, to the East Branch of the Russian River to generate power in the Potter Valley plant of the Pacific Gas and Electric Company.

The Russian River system flows through a narrow, limited valley, the central part of which broadens out enough to permit considerable agriculture near Cloverdale, Geyserville, and Healdsburg. The surrounding hills, which are part of the Coast Range, rise to slightly more than 4,200 feet in elevation.

Climatic extremes range from short, rainy winters to long, hot, dry summers, seldom relieved by rain except in the headwater areas. Nearly 80 percent of the annual rainfall occurs between November and March. As a result of this climatic pattern, the Russian River and its tributaries are subject to great fluctuations in volume of flow. Records at Guerneville have ranged from less than 70 cubic feet per second (c.f.s.) to 89,000 c.f.s. The lower sections of many tributaries become intermittent during the summer months.

Chemical analysis of the river water reveals no apparent problem. The dissolved oxygen content is satisfactory for anadromous fishes except in a few extremely limited areas in the main river above the mouth of the East Branch in the summer, where the entire flow of the river is derived from ground waters a short distance upstream. Summer water temperatures reach 80 degrees F. in the lowermost part of the river.

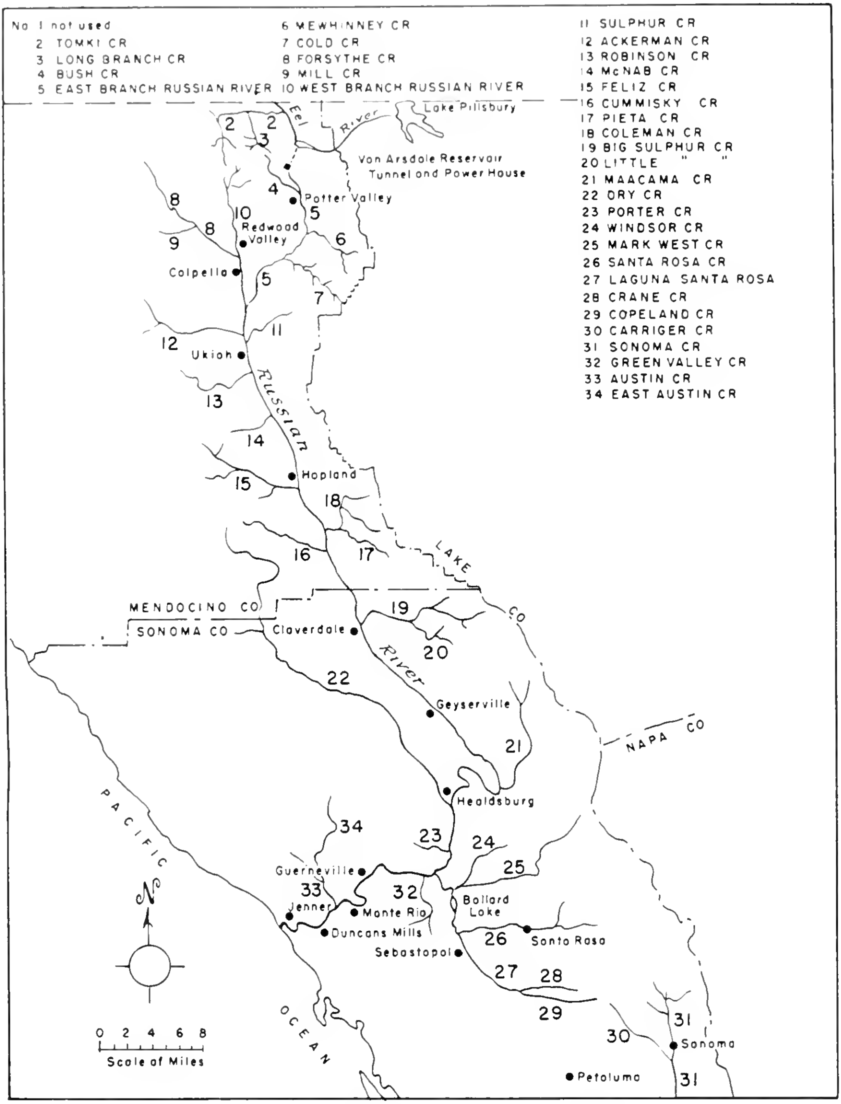

FIGURE 1. The Russian River drainage, California.

THE FISHES AND THE FISHERY OF THE RUSSIAN RIVER

At least 32 species of fishes are known from the freshwater portion of the Russian River (Table 2). Of this number, 21 are native and 11 are introduced forms[3].

The principal fishery of the Russian River in the winter is for steelhead trout and is of considerable magnitude. Unpublished records of the Department of Fish and Game have shown a projected high of 81,000

[3] Marine forms which only occasionally enter the river are not included in the list.

angler days of use for the peak month of December, 1953, with a projected catch per unit of effort figure of 0.32 steelhead per angler day. The recreational value of the fishery is quite important. Silver salmon

TABLE 2

Fishes of the Russian River

Common name	Scientific name
Family Petromyzontidae. Lampreys.	
1. Pacific lamprey	*Entosphenus tridentatus*
2. Brook lamprey	*Lampetra planeri*
Family Acipenseridae. Sturgeons.	
3. White sturgeon*	*Acipenser transmontanus*
4. Green sturgeon*	*Acipenser medirostris*
Family Clupeidae. Herrings.	
5. American shad†	*Alosa sapidissima*
Family Salmonidae. Salmon and trout.	
6. Pink salmon*	*Oncorhynchus gorbuscha*
7. Silver salmon	*Oncorhynchus kisutch*
8. King salmon	*Oncorhynchus tshawytscha*
9. Brown trout†	*Salmo trutta*
10. Rainbow-steelhead trout	*Salmo gairdnerii*
Family Catostomidae. Suckers.	
11. Western sucker‡	*Catostomus occidentalis*
Family Cyprinidae. Minnows.	
12. Carp†	*Cyprinus carpio*
13. Greaser blackfish	*Orthodon microlepidotus*
14. Hardhead	*Mylopharodon conocephalus*
15. Hitch	*Lavinia exilicauda*
16. Sacramento squawfish	*Ptychocheilus grandis*
17. Splittail	*Pogonichthys macrolepidotus*
18. Venus roach	*Hesperoleucus venustus*
Family Ictaluridae. Catfishes.	
19. White catfish†	*Ictalurus catus*
Family Poeciliidae. Top-minnows.	
20. Mosquitofish†	*Gambusia affinis*
Family Serranidae. Sea basses.	
21. Striped bass†	*Roccus saxatilis*
Family Centrarchidae. Sunfishes.	
22. Smallmouth bass†	*Micropterus dolomieu*
23. Largemouth bass†	*Micropterus salmoides*
24. Green sunfish†	*Lepomis cyanellus*
25. Bluegill†	*Lepomis macrochirus*
26. Sacramento perch	*Archoplites interruptus*
27. Black crappie†	*Pomoxis nigromaculatus*
Family Embiotocidae. Viviparous perches	
28. Tule perch	*Hysterocarpus traskii*
Family Cottidae. Sculpins.	
29. Riffle sculpin	*Cottus gulosus*
30. Prickly sculpin	*Cottus asper*
31. Aleutian sculpin	*Cottus aleuticus*
Family Gasterosteidae. Sticklebacks.	
32. Three-spined stickleback	*Gasterosteus aculeatus*

*Forms not observed during the project but known to exist in the system.
†Introduced forms not native to California.
‡Some of the suckers killed may possibly have been the Humboldt sucker, *Catostomus humboldtianus*, although no attempt was made to distinguish between the two species in the field.

contribute a brief but often excellent secondary winter fishery in the lower portion of the river. King salmon are rarely taken.

The summer fishery of the Russian River consists almost wholly of yearling steelhead caught in the tributaries during the trout season, especially around the opening and closing of the season. Smallmouth bass, American shad, striped bass, white catfish, green sunfish, black crappie, and bluegill all provide a portion of the summer fishing. During the trout season, various rough fish, particularly Sacramento squawfish, are also caught.

The present stocking of fish in the Russian River drainage consists of juvenile steelhead derived from salvage operations in the same watershed. In some dry years as many as 350,000 rescued fish are planted.

THE CONTROL PROJECT

Methods

Dry cubé powder, containing between 2 and 5 percent rotenone, was applied by several different methods, depending upon the volume of water encountered and the degree of access to the stream channel. The simplest method was to put a measured amount of the powder into the stream a short distance above a falls or riffle. The churning action of the falls and the turbulence for some distance below mixed the powder with the water. Another method was to put from 1 to 10 pounds of the powder in a wet burlap sack and to "dunk" this in the stream at intervals while on foot or in a boat (Figure 2). This method was slow, laborious, and resulted in uneven application, although requiring a minimum of equipment.

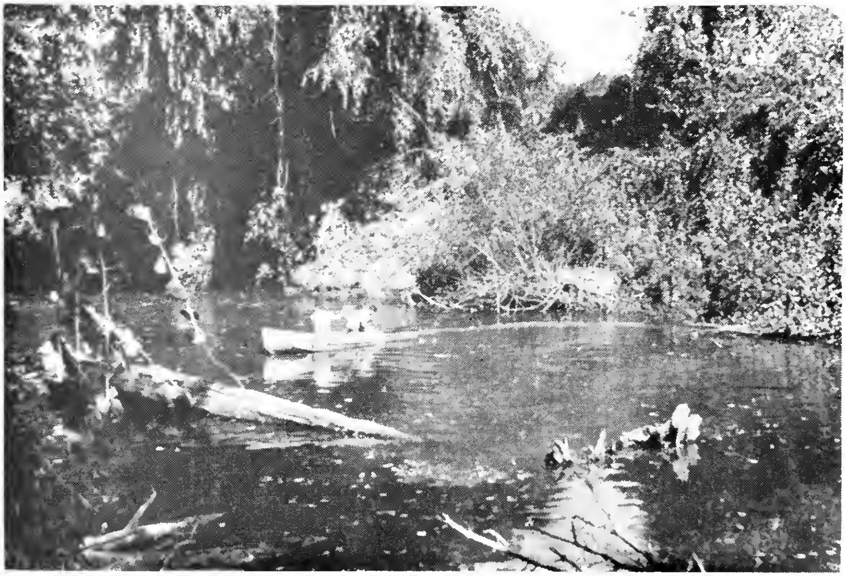

FIGURE 2. Applying cubé powder by boat in lower Mark West Creek.

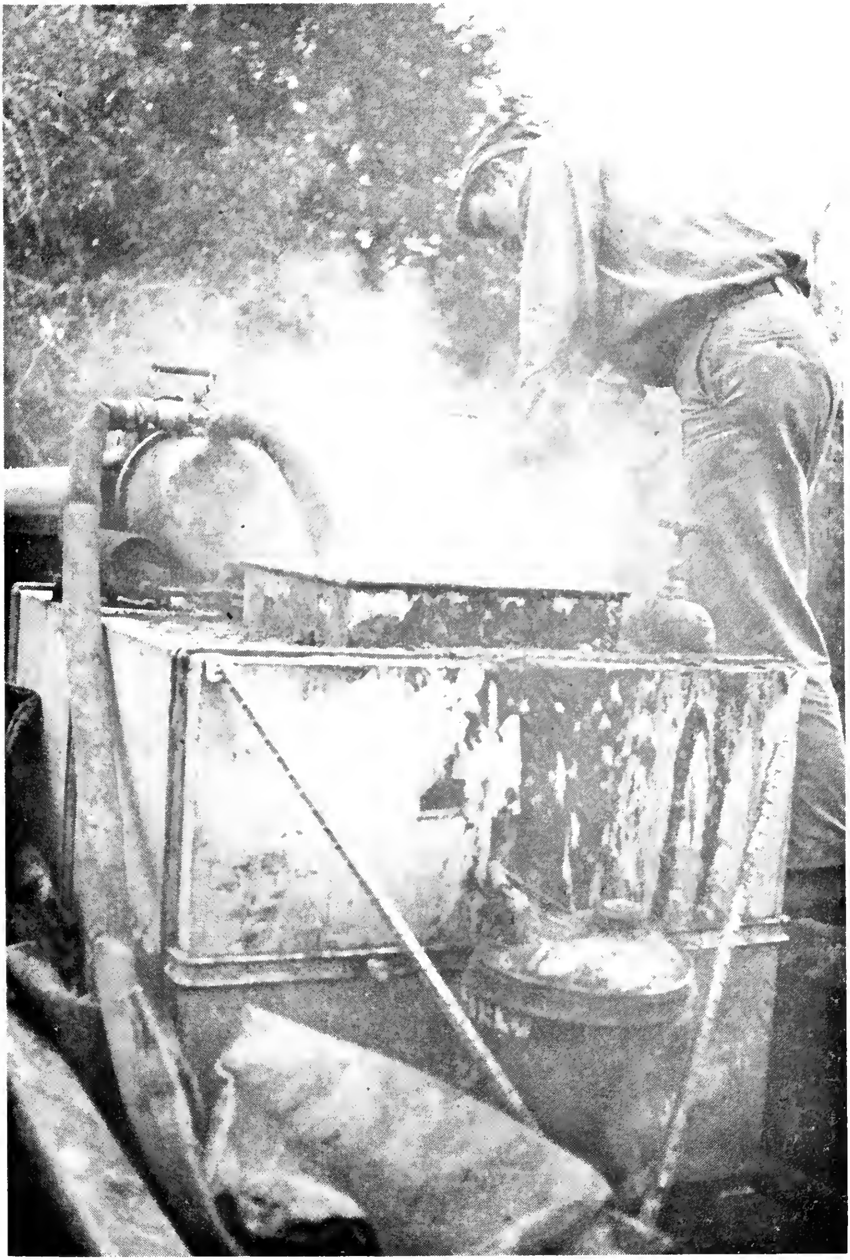

FIGURE 3. The "Cubé Emulsifier" in action. A 50-pound sack of cube powder has just been dumped into the tank and the outboard motor is running.

Two quite successful ways of applying the chemical utilized a premixed solution of cubé powder and water. One was by means of a four-gallon capacity back pump. Equipped with a spray nozzle, the pumps were used where vehicles could not go. The operators applied a continuous spray of the mixture to the water. Two men were required for this method, one carrying a pack loaded with cubé powder in order to refill the pump. The other quite successful means of applying the chemical was through the use of the "Cubé Emulsifier" (Figures 3 and 4). This apparatus was designed by the junior author. The Cubé Emulsifier consisted of a tank carried on a jeep pickup truck, an air-cooled outboard motor which mixed the powder with water, and motor-driven pumps used to fill the tank and to spray the mixture into the stream.

The determination of how much rotenone to use for the project posed an extremely difficult problem. Extreme variations in flow and temperature existed in each of the tributaries, as well as in various stretches of the main river. In the main river, toward the end of the project a heavy rainstorm increased the flow to more than 600 c.f.s. This required considerably heavier doses of cubé powder and reduced the cumulative effect of the powder coming downstream from previous applications. Further complications existed because some of the cubé powder had apparently lost some of its strength. Although chemical assays were made of this material, the results were not uniform and the minimum known rotenone content was 2 percent.

Difficult access to certain areas of the drainage was another reason why the amount of rotenone required could not be predetermined accurately. Once the treatment was started on a stream, it had to continue without lengthy lapses if the rough fish were to be prevented from entering treated areas. This required the introduction of varying amounts of the chemical, depending upon the distance between access points. Methods of testing the rotenone content of the treated water were relatively ineffectual because of continuous variations in the thoroughness of the mixing by the current. Figures 5 and 6 show examples of the extremes in channel conditions encountered during chemical treatment.

It was concluded that rotenone would have to be used in quantities many times the estimated amount necessary to kill fish life. Careful and immediate checks of the treated areas were made more or less continuously. Where there was any doubt, the rate of application was increased and the area retreated. Deep pools were usually additionally treated with cubé powder "mud balls" to get the chemical down to the bottom.

For spraying, one pound of cubé powder was mixed with four gallons of water in a back pump. This four-gallon mixture was applied, in tributaries, to about a 100-yard section of the stream where the flows were from four to five c.f.s., to give a minimum concentration of slightly more than 9.2 parts per million (p.p.m.) of 5 percent cubé powder.[4]

On the tributaries the back pump operator made certain that he managed to spray the entire surface of the water. The cumulative

[4] Although 0.5 p.p.m. of 5 percent cubé powder are considered lethal for most fishes, carp have been known to withstand up to 50 p.p.m.

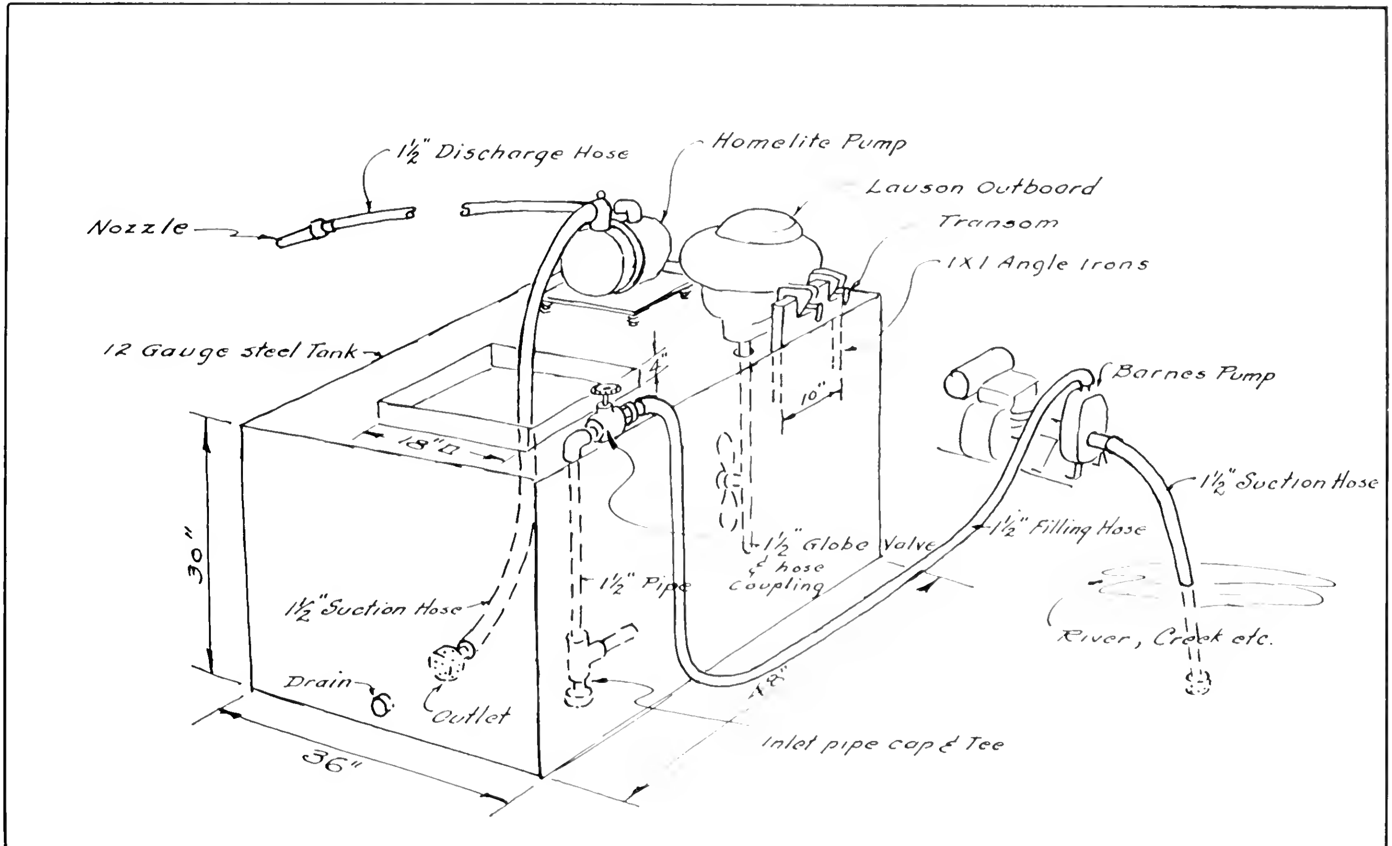

FIGURE 4. Diagram of the "Cubé Emulsifier", an apparatus for mixing and applying cubé powder.

FIGURE 5. The upper portion of Ackerman Creek, showing one type of channel encountered in the chemical treatment project.

effects of the mixture appeared to make up for any localized sublethal concentrations.

At one point in the treatment program fluoresceine ("Sea Dye") was mixed with the cubé powder mixture in a ratio of one-quarter of a

FIGURE 6. This ditch-like, nearly stagnant section of Santa Rosa Creek contained many carp.

pound of dye to 250 gallons of the mixture in an attempt to follow the progress of the cubé powder downstream. Results were disappointing, for in flows over 10 c.f.s. the dye soon became diluted and disappeared. It was noted, incidentally, that the effects of the rotenone consistently showed up ahead of the dye. A heavier concentration of the dye might have given better results.

In order to speed up the operation in the main river and its principal tributary, the East Branch, arrangements were made with the Pacific Gas and Electric Company to shut down its Potter Valley diversion from the Eel River. The decreased flow concentrated the fish life and reduced the amount of cubé powder needed. A similar though smaller shutdown was made by the Santa Rosa Sewage Treatment Plant, in order to facilitate operations on Mark West Creek and lower Santa Rosa Creek.

Data accumulated by pretreatment sampling of the tributaries were used to determine not only which streams should be treated but also at what point on the stream treatment should begin. Streams containing Sacramento squawfish were treated upstream to a point where that species was no longer found. The maximum upper limit for any stream was chosen as that point where young steelhead or trout outnumbered the rough fish approximately 100 to 1. The downstream limits were usually automatically fixed by the point where the stream went underground or dried up. On the main river the downstream limit was set at the summer recreation dam at Healdsburg. This point was chosen because it was believed that the dam was a partial barrier to rough fish moving upstream during the summer period of low flow. Not enough was known of the fish population in the main river below this point to risk a possible kill of game fish.

ROUGH FISH CONTROL ON THE TRIBUTARIES

Pilot Experiments, 1952-53

Three streams were used for initial experiments in the chemical control of rough fish in the Russian River drainage. These were Big Sulphur Creek (1952), Dry Creek (1952 and 1953), and Maacama Creek (1953).

Big Sulphur Creek

Big Sulphur Creek, Sonoma County (Figure 7), was chosen for the initial sampling for several reasons. Local interest in rough fish control was high. A natural falls near its mouth acted as a rough fish barrier. The stream was safe for experimenting, since its mouth was dry in the summer and there was no danger of the chemical reaching the main river. Access was excellent throughout most of its length. Pretreatment sampling showed that rough fish were abundant, although the stream had a past history as a steelhead nursery.

The treatment began on October 9, 1952, when the mouth of the creek was still dry, using burlap sacks containing cubé powder. It began about one mile below The Geysers resort and continued downstream 13 miles to where the stream dried up. Little Sulphur Creek, the major tributary, was treated beginning October 11, 1952, starting at a point about three-quarters of a mile upstream from the mouth

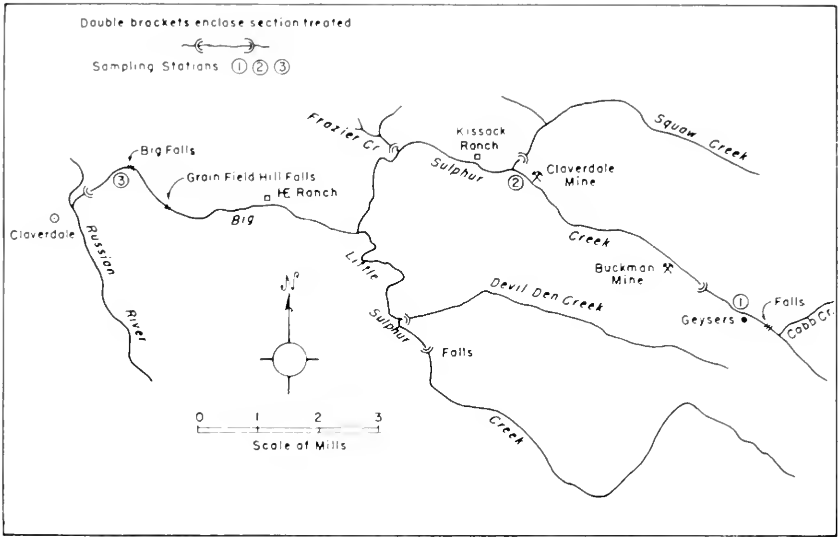

FIGURE 7. Map of Big Sulphur Creek drainage, showing sections chemically treated to contral raugh fish, and sampling stations.

of Devil Den Creek and continuing five miles to the junction with Big Sulphur Creek.

Dry Creek

Partial chemical treatment of Dry Creek, Sonoma County (Figure 8), was conducted between November 2 and 16, 1952. Treatment began a short distance above the mouth of Cherry Creek and continued eight miles downstream to a point where the creek went underground. Application was by burlap sack and back pump. Subsequent examination showed that the partial treatment was not successful, however, and a complete treatment was recommended for 1953.

There were two additional reasons why Dry Creek was chosen for chemical treatment again in 1953. First, it was important to treat a stream which contained no barriers to rough fish, in order to learn the rate of rough fish re-entry. Second, it was necessary to try out rough fish control on a large scale in order to perfect techniques which could be applied to the entire Russian River drainage.

Following the preliminary sampling, Dry Creek and its major tributaries, Gallaway, Cherry, Warm Springs, Pena, and Mill creeks, were chemically treated with about 950 pounds of cubé powder from about one-half mile below Yorkville to a point where the creek dried up. This took place between October 5 and 11, 1953, and included over 63 miles of stream. The project was accomplished by five two-man crews, plus two helpers and five service vehicles. A total of 84 man days was required, although not all of this was spent in actual application of the chemical. A visual and spot-rotenoning recheck of the area eight days later revealed a nearly complete kill, with the exception of a minor pool containing a few dozen sticklebacks, which were destroyed.

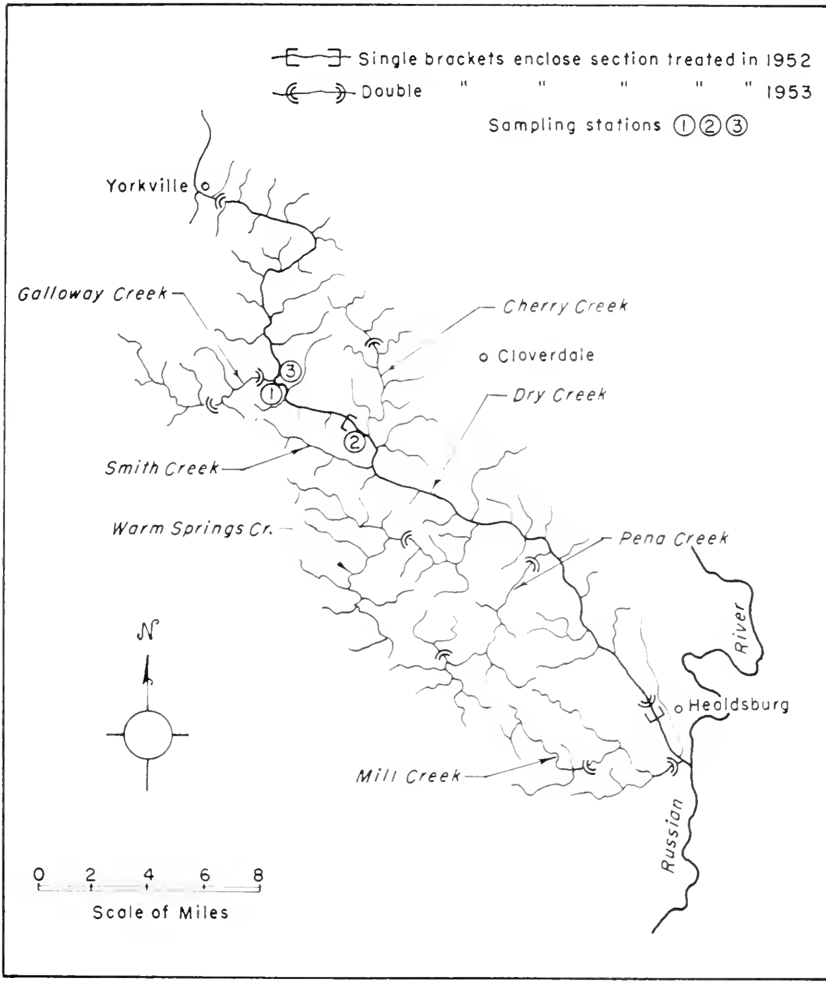

FIGURE 8. Map of Dry Creek drainage, showing sections chemically treated to control rough fish. Sampling stations are numbered.

The Dry Creek treatment showed the value of back pumps in applying the cubé powder (Figure 9) and the efficiency resulting from the use of two- and four-man back pump crews, each assigned to a two- to five-mile stretch of the creek and operating on their own. This released supervisors for coordination and liason activities, and rechecks of treated areas.

Maacama Creek

Immediately following the Dry Creek treatment of 1953, rough fish control work began on Maacama Creek (Figure 10). This creek was chosen as an experimental stream in order to gain supplemental data. It was possible on this stream to check the effect of erecting a temporary flashboard dam about two and one-half miles above the mouth

FIGURE 9. On this section of Dry Creek the use of two 2-man crews greatly increased efficiency and speed. Note dead fish in the foreground. *Photograph by E. L. Daggett.*

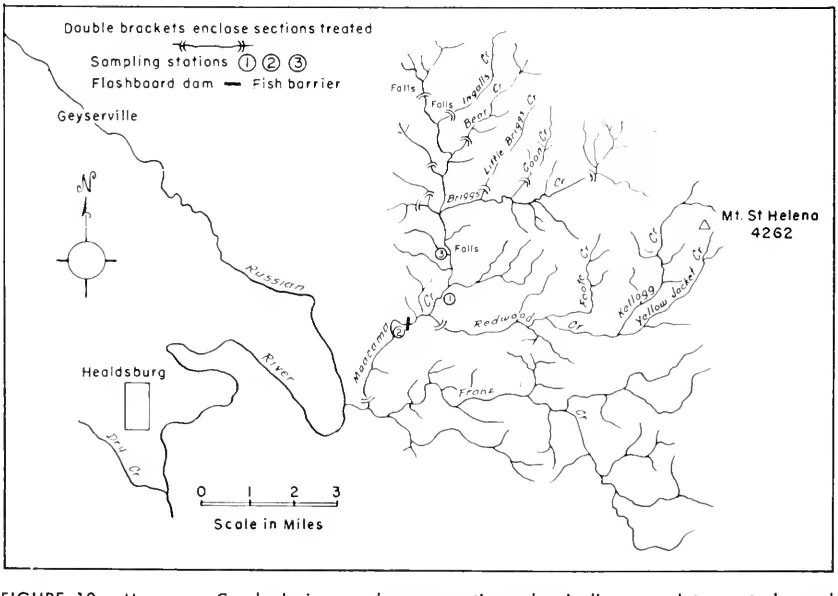

FIGURE 10. Maacama Creek drainage, showing sections chemically treated to control rough fish. Sampling stations are numbered.

after the winter runoff. It was thought that the majority of the rough fish migrated upstream later in the season and could be prevented from re-entering the stream.

Slightly more than 20 miles of Maacama Creek and its tributaries were chemically treated with about 350 pounds of cubé powder during the period from October 13 to 15, 1953. Short sections of the headwater areas were omitted, since rough fish were not observed there in any numbers, while members of the rainbow-steelhead trout complex were abundant. The operation was accomplished by four two-man crews, plus two helpers and four vehicles. A total of 23.5 man days was required, of which 7 man days were spent on preliminary and post surveys and retreatment.

The powder was applied as a mixture with back pumps at a rate of 17.5 pounds per mile.

The flashboard dam was installed late in April, 1954, and again in May, 1955. It apparently was quite successful in blocking re-entry of rough fish, although the chemical treatment of the main river in November, 1954, removed a potential source of rough fish which might have moved upstream before the barrier was installed.

Control on the Remaining Tributaries, 1954

In 1954 the program was further extended as a result of favorable results from the experimental treatment of the three pilot streams and consisted of chemical treatment of all the remaining tributaries where rough fish occurred in abundance. The East Branch of the Russian River was omitted and considered with the main river for later treatment.

No attempt was made to retreat the three experimental tributaries in 1954, despite their being a possible source of rough fish, because it was desirable to avoid interfering with continued post-treatment sampling. The remainder of the treated tributaries are listed in Table 8.

Information gathered during the preliminary field surveys was used to make out a schedule of chemical treatment which would leave sufficient time for treatment in the main river. This part of the program consumed nearly all of the time between August 31, when treatment was begun on Ackerman Creek, Mendocino County, and October 22, when the tributary treatment was terminated with the completion of the lower portion of Windsor Creek, Sonoma County. Twenty tributaries in Mendocino and Sonoma counties, totaling 107 miles in length, were chemically treated. Using a crew of six men, about 300 man days were required. One boat and four service vehicles were used in distributing approximately two tons of cubé powder. It was during this phase of the work that the Cubé Emulsifier was designed, built and first used.

Variations in flow, terrain, and stream channel types were wide. In general, the streams north of Healdsburg had greater flows, steeper gradients, and cleaner channels, although tending to go underground near their mouths. Excellent shade existed in most cases, with little of the characteristic brushy, bankside "jungles" found below Healdsburg. The water was quite clear and flowed through rocky gorges and over boulder-covered bottoms. Although rough terrain required walking out the streams with back pumps, treatment was rapid and the clarity of the water permitted more accurate rechecks for species composition and completeness of kill. Higher flows also carried the cubé powder in lethal concentrations much farther downstream.

Below Healdsburg many of the streams were slow-flowing delta or flood plain types. Frequently the banks were of mud and the water was nearly or completely stagnant. Heavy underbrush grew all the way to the water line, although shade trees were lacking. The water was deep and wide in these sections. Application of the cubé powder by crews walking the banks with back pumps was slow, both because of obstacles and because the pumps were emptied frequently. The Cubé Emulsifier, mounted on the jeep, proved the only feasible means of treatment.

Immediate rechecks of the treated areas on the tributary streams were made during the progress of the treatment to verify preliminary observations of the abundance of rough fish and to make certain the kill was complete.

ROUGH FISH CONTROL ON THE MAIN RIVER

Chemical Treatment

The treatment of the main Russian River and the East Branch of the Russian River followed closely upon treatment of the tributaries. It was completed between November 6 and November 10, 1954, and terminated at the Healdsburg Recreation Dam, covering a distance of about 78 miles. The work was accomplished by a crew of nine men and seven vehicles over a five-day period. A total of 43 man days was required, although not all of this was spent in actual application of the chemical. The average rate of application of the cubé powder was 54.1 pounds per mile.

A nonstop schedule was prepared, in order to maintain a continuous lethal block of the chemical despite dilution. The operation was facilitated by arrangements with the Pacific Gas and Electric Company to shut down their Eel River diversion to 10 c.f.s., in order to reduce the amount of chemical needed and to speed up the operation. The date of the treatment was largely determined by the time when this shutdown could most economically be effected by the company. It was also believed desirable to complete the treatment prior to the onset of the winter rains, which might stimulate the spawning migration of silver salmon and steelhead, as well as carry the accumulated rotenone in in lethal quantities downstream. This was ony partially successful, since rain during the latter part of the treatment raised flows to over 600 c.f.s. and some silver salmon were killed at the mouth of the river.

The first introduction of the chemical was made November 6, 1954, in the tailrace of the Pacific Gas and Electric Company's power plant in Potter Valley. The Cubé Emulsifier, mounted on a jeep, was used to mix the cubé powder, and the mixture was sprayed into the water through a fire hose.

Besides the use of the Cubé Emulsifier, other methods of introducing the chemical, as dictated by expediency and conditions, were used, such as mixing the dry powder with water in a pit dug in the beach beside the river, or by slowly dumping sacks of the dry powder in a riffle or above a falls.

The movement of the chemical in the river was checked by observing the effect upon fish life downstream. Distances traveled by the chemical varied with flows, the amount of chemical introduced, and characteristics of the stream channel. In the upper sections of the East Branch, the low flow of 10 c.f.s. and numerous check dams prevented the chemical from being carried effectively for more than about one mile before additional chemical was needed. The maximum distance and speed traveled by the chemical was recorded during treatment in the Hopland area. In this instance, with the flow about 90 c.f.s., a total of 1,000 gallons of the mix containing 225 pounds of powder was introduced by the Cubé Emulsifier. On the following day the effects of this dose were traced, by means of dead fish in and along the river, for 16 miles. This distance was covered in almost exactly 16 hours. It is possible that the effects might have extended still farther if there had not been additional dilution from Pieta Creek at the lower end, and if a light rain had not begun about the time of the introduction.

Attempts were made to meet changing conditions by increasing or decreasing the amounts of chemical added to the river at various stations. Changes in stream channel characteristics were easily handled, but abrupt changes in weather and flows were more difficult. Intermittent rain fell throughout the latter half of the treatment. In addition, water released by the power company on November 9, 1954, increased the flow in the East Branch from 10 to 100 c.f.s. in a single 24-hour period. The fluctuations in flow shown in Table 3 indicate the effects of both the rain and the later release from the diversion.

Results

Rechecks of the treated areas to determine the completeness of the kill were made almost continuously during the five-day period, including a reconnaissance by boat of a 10-mile section. In no place were live fish discovered. The spreading of the high concentration of the chemical by moving water made adequate coverage much more certain than is the case in lakes and ponds. Dispersal of the chemical appeared excellent, for effects showed up in back eddies and even in connected side pools throughout the treated area. Although most invertebrates were not seriously affected by the rotenone, it was noted that at the point of initial introduction of the chemical a few crayfish started to crawl out of the water.

Effects of the chemical did not automatically stop in the vicinity of the Healdsburg Recreation Dam, where treatment ended. It was expected that the effects would travel up to 10 or 15 miles farther downstream with constantly diminishing strength. The flushing action of the early rain, however, greatly increased the downstream movement of the chemical. In addition, the cumulative buildup of the chemical apparently counteracted the increased dilution caused by the rain. The result was that fish were affected all the way to the mouth of the river at Jenner, a distance of more than 22 miles from the last point at which the chemical was introduced. Carp were observed in distress, but only a small number of them were eliminated, judging by the scarcity of carcasses along the banks later. Other fish were also affected and about 150 silver salmon were killed in the area below Monte Rio.

TABLE 3

United States Gaging Station Records for Various Locations and Dates, East Branch of Russian River and Russian River

		Flows in cubic feet per second				
		East Branch of Russian River near Calpella	East Branch of Russian River near Ukiah	Russian River near Hopland	Russian River near Cloverdale	Russian River near Healdsburg
October, 1954, means		308	303	301	301	311
November, 1954 means		270	259	302	408	770
5-year means for November, 1946-1950		239		321		659
November	1	313	306	304	318	332
	2	288	288	304	318	335
	3	162	153	230	275	335
	4	158	151	183	203	285
	5	94	88	146	175	240
East Branch and main Russian River treatment period	6	22	30	104	131	232
	7	18	13	75	105	180
	8	24	24	75	131	200
	9	26	25	70	131	610
	10	112	105	72	98	130
	11	317	311	172	187	299
	12	327	315	315	366	605
	13	320	294	296	330	517
	14	362	343	334	837	618
	15	552	511	887	1,960	5,580
	16	412	390	722	1,070	2,600
	17	342	321	452	664	1,110
	18	332	315	382	500	1,020
	19	330	312	354	436	914
	20	330	318	342	414	765
	21	327	315	338	390	695
	22	327	315	330	381	645
	23	327	315	330	372	610
	24	327	312	327	363	580
	25	327	315	327	357	559
	26	327	315	323	351	535
	27	327	315	323	318	517
	28	327	315	319	345	499
	29	327	315	319	345	490
	30	327	312	319	342	478

The above figures, with the exception of the five-year means, were obtained from unpublished records (subject to revision) of the Water Resources Division, U. S. Geological Survey.

The five-year means were computed from the reports on Surface Water Supply of Pacific Slope Basins in California for the years 1946 through 1950, inclusive, published by the U. S. Geological Survey.

Immediate checks of the lower river showed that this was not a complete kill of the spawning run.

A list of the species observed, giving approximate distribution, locations of greatest abundance and, wherever possible, size ranges, is shown in Table 4.

Estimates based upon direct observations yielded a weight of from one to one and one-half tons of dead fish per mile for the section of the river above Healdsburg and one-half ton of dead fish per mile in the section below. Observations in the latter section were extremely difficult because of high and turbid water, and for that reason represent a con-

TABLE 4

Sizes and Distribution of Fishes Observed During Treatment of the East Branch and Main Russian River—1954

Species	Where found	Area of greatest abundance	Size range (inches)	Remarks
Pacific lamprey	Throughout treated area	Ukiah		Lamprey ammocoetes greatly outnumbered other species.
Brook lamprey	Only near Ukiah	Not abundant anywhere	6	A few also found in lower Mark West Creek.
Silver salmon	Jenner to Monte Rio	Mouth of river (Jenner)		50%, adults, 50% grilse
King salmon	Mouth of river (Jenner)	Not abundant anywhere	[illegible]	Only 2 adults observed.
Rainbow-steelhead trout	Throughout entire river	Not abundant anywhere	5-25	
Western sucker	Throughout entire river	Throughout entire river	$1\frac{1}{2}$-24	Absent only in extreme upper part of East Branch Russian River.
Carp	River below point 4 miles above Cloverdale	Mouth of Mark West Creek and Duncans Mills	7-35	Majority were adults 14 inches or more in length.
Greaser blackfish	Geyserville to Healdsburg	Not abundant anywhere	5-16	Most were found in Healdsburg gravel pits in river bed.
Hardhead	Potter Valley to Healdsburg	Mouth of East Branch Russian River	4-22	
Hitch	Hopland to mouth of Mark West Creek	Not abundant anywhere	6-10	
Sacramento squawfish	Throughout entire river	Healdsburg and above	3-34	
Venus roach	Throughout entire river	Scarce—mainly at mouths of tributaries	$\frac{3}{4}$-5	
White catfish	Healdsburg and vicinity	Scarce everywhere	6-10	
Striped bass	Guerneville bridge	Not abundant anywhere		Only 2 adults observed; 20 lbs. and 35 lbs.
Smallmouth bass	Mouth of Cold Creek downstream	Monte Rio to mouth	4-14	Only 20 were above 9 inches long.
Largemouth bass	Geyserville side channels	Very scarce everywhere	18	
Green sunfish	Throughout entire river	Geyserville-Healdsburg sloughs	$\frac{3}{4}$-6	Present only in limited numbers.
Bluegill	Geyserville side channels	Very scarce everywhere	4	
Sacramento perch	Geyserville side channels	Very scarce everywhere	$3\frac{1}{2}$-$4\frac{1}{2}$	
Tule perch	Below lower end of Potter Valley	Fairly abundant everywhere	2-6	
Sculpins	Potter Valley area	Very scarce everywhere	7	Only one specimen observed.
Three-spined stickleback	Geyserville and vicinity	Not abundant anywhere	1-3	

servative estimate. The estimated total amount of fish killed was 95 tons.

COST OF THE PROJECT

The costs of the operating phases of the project totaled about $6,000. This is computed on the basis of $2,100 for salaries, $1,400 for operating expenses, and $2,500 for materials. The costs of preliminary and follow-up survey are not included in these figures. The cost of treatment per mile of stream averaged about $20.

EVALUATION

Pretreatment sampling of the fish population, both to determine whether or not a particular stream warranted treatment and to be able to evaluate the results of the treatment by a comparison of the fish populations before and after treatment, was carried out.

Methods

Visual checks were used on most of the shallow tributaries to determine the upstream limits of both Sacramento squawfish and other rough fish. They were also used in a limited way in rechecking some of the tributaries several weeks or months after treatment. Observations on numbers and kinds of fishes killed were also made on foot and by boat, both at 100-foot sections and sometimes continuously, immediately following the treatment. While this method gave a limited qualitative check on live fish, its best use was in a recheck following the kill.

Seines and sampling gill nets were used in deep portions of the main river. This, too, was entirely qualitative. In inaccessible stretches of water, or during periods when the electric shocker was not available, sampling was performed by means of spot rotenoning and a subsequent

FIGURE 11. Part of the crew collecting fish killed by spot rotenone sampling in Forsythe Creek.

count of the dead fish along a given stretch of stream which had been blocked by seines (Figure 11).

Two types of electric shockers were used for sampling. One was a 110-volt A.C. shocker and the other was a 230-volt D.C. shocker. The latter was especially helpful, since fish were attracted to the positive electrode. A 100-foot section was blocked with seines and the area shocked until no more fish appeared. This method frequently revealed a much larger and more varied population of fishes than was observed by a visual check.

Tributary Stream Fish Population Sampling

Big Sulphur Creek

Preliminary sampling on this creek showed that rough fish in the form of suckers, squawfish, and roach composed 95 percent of the fish population. The remaining 5 percent were juvenile steelhead.

Post-treatment sampling in 1953, although limited, indicated that young steelhead made up almost 100 percent of the fish population. Suckers made up the remainder and squawfish and roach were absent. Table 5 compares pretreatment and post-treatment sampling at various stations.

The information on population change indicated by sampling was supplemented by creel checks made during the first few weeks of the trout season in 1953, 1954, and 1955. Prior to 1953, according to wardens' reports, the fishery was poor and sporadic. Only the expert angler was able to make a good catch, usually either just after the opening or just before the closing of the season. On the first two days of the season in 1953, wardens reported that only two of 47 anglers failed to have their limits of 15 juvenile steelhead.

A brief survey of this same stream on May 1, 1954, while not reflecting the same degree of success, did reveal a catch of 252 juvenile steelhead by 30 anglers for a catch per angler day of 8.4 fish. Whether or not the increase in numbers of steelhead was the direct result of the treatment is still questionable. The source of these fish is also unknown, since they were in their second year in the stream and could have come either from the tidewater area near the mouth of the river or from the untreated headwater areas. The latter source is the most likely, but too little is known of fish movement within the drainage system to be certain.

During the winter of 1953-54, further movement of the slide in the area of the falls barrier resulted in a complete block to upstream movement of steelhead, so that some of the value of rough fish control was not fully realized upstream. A separate project has since altered the falls, so that it again acts only as a rough fish barrier.

In 1955 further post-treatment electrosampling was performed on Big Sulphur Creek, as part of the long-term evaluation of the chemical treatment project. The three stations sampled produced 822 juvenile steelhead, 128 suckers, and 170 roach. At one of the stations (Station No. 2) it was found that the suckers were back to about the pretreatment level of abundance, but the steelhead continued to predominate by about 3 to 1. Creel censuses also showed excellent fishing again, as was observed in 1953 and 1954. The over-all picture was quite favorable three years after treatment.

TABLE 5

A Comparison of Fish Population Sampling in Big Sulphur Creek Before and After Chemical Treatment

Species	Station No. 1				Station No. 2				Station No. 3
	Pretreatment 1952	Post-treatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1952	Post-treatment 1953	Post-treatment 1954	Post-treatment 1955	Post-treatment 1955
Rainbow-steelhead trout	35	31	13	38	0	3,393	--	363	421
Western sucker	9	4	12	5	134	23	--	121	2
Sacramento squawfish	0	0	0	0	97	0		0	0
Venus roach	351	544	751	148	0	0	--	0	22

Station No. 1 was located at The Geysers about three-quarters of a mile above start of treatment. An electric shocker was used in sampling. Practically the entire fish population was removed and counted.

Station No. 2 was obliterated by road building in 1954. About 30 rainbow-steelhead trout and a few suckers were observed in the area that year.

Dry Creek

Visual observations of Dry Creek in 1952 had shown that many rough fish were present, but no quantitative sampling was done. A check of the fishes killed in the treatment showed that roach and suckers predominated, with squawfish a close third. Trout, although abundant in a few areas, were generally scarce. Tule perch were well distributed in small numbers, but no smallmouth bass were found. The figures on the kill represent estimates made during brief observations. The 1953 electrosampling indicated that there was some reduction of rough fish in the treated area and an accompanying increase in the numbers of young steelhead. Table 6 shows, under the column "Station No. 2", the relatively large number of steelhead found in a 100-foot section. This is larger than the total number of steelhead estimated killed in the entire eight-mile treated area in 1952.

Population sampling was carried on in 1953 and a survey was conducted on the tributary streams to determine the upstream limits of squawfish and roach. In referring to Table 6 again, it may be seen that six species of rough fish made up the bulk of the pretreatment fish population at each of the two sampling stations checked by electric shocker in 1953. The average percentage of rough fish in the population was 84.

Post-treatment sampling in the Dry Creek drainage in 1954 revealed that hardheads, cottids, and sticklebacks virtually had been eliminated. Suckers, squawfish, and roach were still found in greatly reduced numbers. It is possible that they migrated into Dry Creek from the Russian River during the winter or that some of them were overlooked in determining the starting point of treatment in the tributary headwaters. It is encouraging to observe that in the first year following treatment the rough fish did not make a complete comeback, even though no barrier existed. No tule perch showed up in the 1953-54 pretreatment and post-treatment sampling.

Further sampling in Dry Creek in 1955 showed that this stream was returning rapidly to the pretreatment condition. Roach, suckers, and squawfish increased beyond the 1954 figures, while the juvenile steelhead population appeared to decline. The most obvious source of the rough fish was the main river. No barrier existed for the eight months when the creek was "live" to its mouth. Dry Creek was treated again in the summer of 1955, when spot rotenoning was undertaken to kill concentrations of squawfish.

Maacama Creek

Preliminary population sampling and a check on upstream limits of rough fish were made prior to treatment in 1953. Table 7 shows the sampling results. Seven rough fish and two pan fish species were originally present. Roach made up about 50 percent and squawfish about 16 percent of the rough fish. Juvenile steelhead made up 15 percent of the population.

The results of the Maacama Creek chemical treatment may be divided into two parts. At Station No. 2, in the area below the flashboard dam installed April 14, 1954, electrosampling showed a large increase in roach. Green sunfish and tule perch were also found in larger numbers than before treatment, and bluegills appeared where none had been

TABLE 6

A Comparison of Fish Population Electrosampling in Dry Creek Before and After Chemical Treatment

Species	Station No. 1			Station No. 2			Station No. 3		
	Pretreatment	Post-treatment	Post-treatment	Pretreatment	Post treatment	Post-treatment	Pretreatment	Post-treatment	Post-treatment
	1953	1954	1955	1953	1954	1955	1953	1954	1955
Rainbow-steelhead trout	0	22	51	387	56	37	Not	402	10
Western sucker	11	17	19	260	120	151	Sampled	68	9
Hardhead	2	0	0	15	0	0		0	0
Sacramento squawfish	36	0	8	119	6	65	in	15	2
Venus roach	7	5	126	985	18	19		27	0
Sculpin	0	0	0	3	1	0	1953	0	7
Three-spined stickleback	0	0	0	123	10	0		0	3

Station No. 2 is located in a section of the stream included in the 1952 partial treatment. Lampreys are not included, although they appear to have been reduced in numbers

TABLE 7

A Comparison of Fish Population Electrosampling in Maacama Creek Before and After Chemical Treatment

Species	Station No. 1			Station No. 2			Station No. 3		
	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955
Rainbow-steelhead trout	21	81	115	12	9	192	Not	127	356
Western sucker	8	0	1	18	4	9		2	1
Hardhead	0	0	0	13	0	0	Sampled	0	0
Sacramento squawfish	6	0	0	38	7	27		0	0
Venus roach	117	38	130	0	102	202		21	67
Bluegill	0	0	0	0	1	0	in	1	0
Green sunfish	0	0	1	3	20	2		0	0
Tule perch	0	0	0	1	10	2		0	0
Sculpin	0	0	3	1	1	0	1953	3	2
Three-spined stickleback	0	2	1	0	0	0		1	2

Stations Nos. 1 and 3 are located above a flashboard dam which was operated in the spring prior to the 1954 sampling. Station No. 2 is located below the flashboard dam.

observed earlier. Suckers, hardheads, and squawfish showed an appreciable reduction, but the steelhead population remained at its former low level. In the areas above the flashboard dam the steelhead population increased at least fourfold, while all rough fish showed a marked reduction in the population, with hardhead, squawfish, green sunfish, and tule perch absent. These findings, while less striking than in Big Sulphur and Dry creeks, show the same trend. It is evident that the installation of the flashboard dam was of value in preventing the reentry of rough fish.

In 1955 additional sampling showed that the ratio between young steelhead and rough fish had improved still more in favor of the former. Steelhead had increased to as much as 20 times the abundance found in 1954, while the population of roach, the only rough fish showing a significant increase, about tripled.

Other Tributaries

Extensive preliminary field surveys were conducted in 1954.

Electrosampling on Mark West Creek and spot rotenoning on East Austin Creek showed that these streams were infested with rough fish far exceeding the young steelhead in numbers. Results were similar to those which were found on the experimental streams. Visual checks on the other tributaries showed the same condition.

Population checks during treatment were made on nine of the tributaries by selecting random 100-foot stretches and counting all the dead fish seen. The percentage composition of the species was computed from these checks (Table 8). Two streams were too turbid to afford rechecks of much accuracy, but because of the amount of cubé powder used, there was little doubt that a high percentage of kill had occurred. Samples of the kill taken on the tributary streams indicated that the fish population was composed of an average of 14 percent game fish, including smallmouth bass and green sunfish, and 86 percent rough fish.

Evaluation by electrosampling the fish population was carried out in 1955 at selected stations on five of the tributaries for which pretreatment data were available. Table 9 shows the differences between pretreatment and post-treatment for these streams. The number of yearling and fingerling steelhead increased from 157 in 1954 to 1,673 in 1955. The change in abundance of rough fish for the same period was from 895 in 1954 to 130 in 1955, or to one-seventh of their former abundance. Exceptional trout fishing on some of the tributaries during the opening of the 1955 season was also observed.

Some of the five streams exhibited individual trends in population shift considerably at variance with the over-all picture. For example, on Forsythe Creek and the West Branch of the Russian River, Sacramento squawfish appeared at sampling stations where none were found before treatment. In the case of the latter stream, there was an almost equal increase in abundance of both juvenile steelhead and squawfish. Mark West Creek showed a 66 percent decrease in the numbers of juvenile steelhead in 1955. At the same time, however, there was a 92 percent decrease in rough fish.

Four other treated tributaries for which no comparable pretreatment figures were available were sampled with an electric shocker in

TABLE 8

Percentage Composition of the Fish Populations at Various Stations on Selected Tributary Streams of the Russian River Chemically Treated From August Through October, 1954

Stream	Game and pan fish				Rough fish					
	Brown trout	Rainbow-steelhead trout	Small-mouth bass	Green sunfish	Western sucker	Hardhead	Sacramento squawfish	Venus roach	Tule perch	Sculpin
Ackerman Creek		1.83			23.39		12.91	58.87		
Robinson Creek		7.31			15.11		0.85	46.09		0.34
Feliz Creek		22.73			17.17		8.43	51.67		
Forsythe Creek	0.33	21.61	3.35	1.17	15.77		2.88	54.86		
Mill Creek		21.23		3.91	15.08			58.10		1.68
Sulphur Creek (Mendocino County)					8.68		23.29	68.03		
Russian River, West Branch		0.19	9.32		29.15	3.66	15.47	38.77	2.81	
McNab Creek		8.95			18.69		7.53	61.83		
Porter Creek		18.05			22.55		9.03	45.11		5.26
Percentage by species, all streams combined	0.37	11.50	1.16	0.56	21.86	0.41	8.98	51.01	0.31	0.81
Percentage by type		13.59					86.11			

TABLE 9

Comparison of Electrosampling Results Before (1954) and After (1955) Chemical Treatment of Selected Tributaries of the Russian River

Name of stream	Species																				Types					
	*Trout		Western sucker		Sacramento squawfish		Venus roach		Mosquito fish		Smallmouth bass		Green sunfish		Tule perch		Sculpin		Stickleback		*Trout		Other		Totals	
	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955
Feliz Creek	6	986	29	0	31	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	686	986	113	0	119	986
Forsythe Creek	35	325	22	0	3	16	85	0	0	0	12	0	2	0	0	0	0	0	0	1	35	325	124	17	159	342
Mark West Creek	71	24	1	0	1	0	324	0	0	18	0	0	0	14	1	0	27	0	106	7	71	24	463	39	534	63
Robinson Creek	13	269	17	0	2	0	21	0	0	0	0	0	0	0	0	0	21	0	0	1	43	269	61	1	104	270
Russian River, West Branch	2	69	59	2	37	68	0	0	0	0	38	0	0	2	0	0	0	0	0	1	2	69	134	73	136	142
Totals	157	1,673	131	2	74	84	483	0	0	18	50	0	2	16	1	0	48	0	106	10	157	1,673	895	130	1,052	1,803

* Includes resident rainbow trout and juvenile steelhead trout.

1955. The results are shown in Table 10. The favorable trend in species composition was evident here, as in other treated streams. Rough fish made up only about 10 percent of the total number of fish one year after treatment. The majority of the remainder were juvenile steelhead and a few juvenile silver salmon.

TABLE 10

Electrosampling Results for 1955 on Four Russian River Tributary Streams for Which No Pretreatment Data Are Available

Streams	Species							Total rough fish	Grand totals
	Trout*	Silver salmon	Western sucker	Sacramento squawfish	Venus roach	Sculpin	Stickleback		
Cummunsky Creek	83	0	1	0	13	0	0	14	97
East Austin Creek									
Station No. 1	139	0	0	2	54	1	0	57	196
Station No. 2	278	33	0	0	14	8	0	22	333
Mewhinney Creek	14	0	0	4	0	0	0	4	18
Pieta Creek	319	0	0	0	0	0	0	0	319
Totals	833	33	1	6	81	9	0	97	963

* Includes resident rainbow trout and steelhead trout.

From the first year's follow-up electrosampling on a number of the treated tributaries of the Russian River, it was concluded that in general the chemical treatment was at least temporarily successful. It resulted in a reduction in the numbers of rough fish, with a simultaneous increase in juvenile steelhead, in nearly all of the tributaries. Sampling showed that juvenile steelhead, together with other game fish, made up less than 1 percent of the fish population before treatment. In 1955, about 67 percent of the population was in this category, increasing about 13 times. Of the remaining 33 percent, 17 percent were roach and 6 percent squawfish. No smallmouth bass were observed, but suckers, sculpins, sticklebacks, and tule perch were found in small numbers.

Sampling the Main River

Preliminary work on the Russian River rough fish control project, especially on the three experimental streams, raised a pertinent question concerning the fish population in the main river. If juvenile steelhead were scarce in the tributaries, was it because they had sought refuge in the larger water? However, poor angler success for trout in the main river suggested a very low population there. Fishing for other game species was also poor. It was suspected, therefore, that the main river also had a large rough fish population. In 1953, advantage was taken of the emergency shutoff of the Pacific Gas and Electric Company power plant diversion in Potter Valley to sample fish populations between October 24 and October 27, 1953. During this period a survey of the fish population was made at selected stations between Potter Valley on the East Branch and Hacienda on the main Russian River. Although the flow was cut almost to zero at the powerhouse, the effect on the river below was to reduce its flow to 50 c.f.s. The fish population was sampled by beach seines, gill nets, and spot rotenoning. The results showed a population of 90 percent rough fish, 8 percent warmwater game fish, and 2 percent resident trout and juvenile steelhead.

An additional survey, using beach seines, was made in July of 1954 in a 20-mile section between Mirabel Park and Jenner. This section has a low gradient and, with the exception of the brackish estuary, appears to offer an ideal habitat for warmwater fishes. The results revealed a population dominated by rough fish. Carp were most prominent by weight and by numbers, with suckers second in abundance, among the rough fish. Warmwater game fish were scarce, with smallmouth bass being the only species taken in significant numbers. In the lowermost stretch of the river, shad fingerlings were the most abundant of any species encountered.

Rechecks of the fish population following treatment of the main river revealed 22 species of true fishes and 2 species of lampreys. Of the dead fish observed in the treated area, suckers were estimated to represent approximately 90 percent of the total population. Sacramento squawfish were second in abundance, comprising about 5 percent. Tule perch accounted for about 2 percent and smallmouth bass less than 0.5 percent. The remaining 14 species were scarce and together comprised only 2.5 percent of the population. The rough fish, therefore, represented at least 97 percent of the fish population.

The only evaluation of the results of the control program on the main river has been in the form of observations of summer fishing. Prior to treatment fishing in this part of the river was primarily for warmwater fishes. The spring and summer of 1955 saw a large, successful summer fishery for trout (juvenile steelhead) where none had existed for years. Whether or not this fishery is only a temporary condition will be revealed by further evaluation work.

The Follow-up Program

The follow-up program consists of a five- to eight-year study of changes in the fish population in the Russian River and its tributaries. Through population sampling, an attempt will be made to discover the recovery rate of the rough fish, the amount of increase in the juvenile steelhead population, and the length of time that the beneficial results of the treatment will last. Winter creel censuses on the main river should reflect the effect of the treatment project upon the runs of adult steelhead, while censuses during the trout season should give an idea of the role of juvenile steelhead in the summer fishery.

DISCUSSION

Sources of Reinfestation

Final examination of the treated areas revealed no living fish, but it is scarcely conceivable that every pool supporting rough fish was discovered and treated. Furthermore, it is known that numerous sources for reinfestation of rough fish exist. As mentioned earlier, preliminary sampling of the upstream limits of rough fish in the tributary streams revealed high concentrations of salmonids in many instances. Where the latter were in a ratio of more than 100 to 1 over the rough fish, it was not believed justifiable to treat. In other cases, again because of the preponderance of salmonids, the upstream limits were fixed by the extent of the distribution of Sacramento squawfish. Therefore, the headwaters still contained some rough fish after the treatment was concluded.

Three streams, Big Sulphur, Dry, and Maacama creeks, were treated the previous two seasons but not in 1954. It was learned through subsequent electrosampling that large rough fish had managed to enter Dry Creek during the winter of 1953-54. Some rough fish may also have entered the two other streams.

It has already been mentioned that, although the lowermost application of rotenone was made at Healdsburg, the effects were felt all the way to the mouth of the Russian River. The resulting kill was not universal and many undesirable fish in that area were still free to travel upstream. The Healdsburg Recreation Dam acts only as a partial fish barrier. Literally thousands of carp were made sick by the exposure to cubé powder below Healdsburg. Judging from the few dead carp found, however, most of them probably recovered.

Another source of rough fish is by way of the Pacific Gas and Electric Company diversion from Van Arsdale Dam on the Eel River to the headwaters of the East Branch of the Russian River in Potter Valley. Although carp, Sacramento squawfish, and the majority of other warmwater fishes are absent from the Eel River, Humboldt suckers, green sunfish, and sculpins are present in the river above Van Arsdale Dam.

Many farm ponds are scattered throughout the Russian River drainage. A large share of these have been stocked with fish by the California Department of Fish and Game as part of its farm fish pond program, but others have been subject to indiscriminate and unauthorized planting with a variety of fishes by the owners. The farm ponds are located on the tributaries and, in general, are inaccessible to rough fish from the river. Rough fish existed in these tributaries prior to construction of the ponds, however, and the ponds may thus present another source of infestation.

A final source is the accidental or deliberate spread of rough fish by anglers and other persons. Some individuals attempt independently to help fish conservation by planting fish, while anglers frequently use bait minnows obtained from different drainages.

The Role of Public Relations

Public relations was found to play a major role in the rough fish control project. Although attention was given to this aspect of the work through newspapers, radio, and word of mouth, it was evident from complaints that still more effort could have been expended. It is obvious that public support is valuable in such a drastic management procedure as chemical control of rough fish in an entire drainage system.

Thorough advertisement and a program of public education regarding the purpose of the project and the manner of accomplishment are needed. If this is done, it should, in a large measure, offset adverse criticism.

Observed Effects of Rotenone

The effects of rotenone should be considered in three categories. First is its general killing effect as it varied under different flow conditions. One thing of interest is the apparent flushing action of the rapidly increasing flows caused by rain. During the tributary treatment this phenomenon was first noticed and it served to explain in part why the main river treatment carried so far. Near the end of the treatment program in East Austin Creek a steady two-day rain occurred. Until that time, the distance the chemical traveled downstream was limited to not more than a mile. It is thought that a low flow and dilution were responsible for the limited effect. Following the rain, however, fish in untreated Austin Creek, of which East Austin is a tributary, began dying and the effects were noted as far downstream as the Russian River. It is believed that much of the cubé powder in the initial application, in spite of its suspension in highly divided form in the water, had settled and otherwise become static on the sides and bottom of the streams. The flushing of the channel by rain, which at least doubled the flow, seems to have churned up the chemical and pushed it farther downstream, counteracting the dilution to some extent.

Similar changes occurred in the Russian River. Treatment began in Potter Valley on November 6. Intermittent rain fell throughout the latter half of the treatment, which ended on November 10. Rain on the previous day, coupled with the release of 100 c.f.s. of water from the powerhouse diversion, caused the river to rise several feet, with effects resembling those on East Austin and Austin creeks. In other tributary streams, where the flow remained stable, no such action was observed.

There were noticeable differences in the effects of the rotenone upon the various species of fishes in the drainage. It took from as little as 10 minutes to as much as two hours for the chemical to kill fish. The speed with which the chemical killed depended upon species, temperature, and the character of the stream bottom. Despite the low flow and the shallow areas in the headwaters of the tributaries, the low temperatures required a longer exposure of the fish before they died. In lower stretches, where temperatures were higher, killing was much quicker. Deep pools also caused the rotenone to take longer to become effective, mainly because of difficulty in spreading the mixture throughout the lower levels of the pool and because of underflow.

In general, fish of any given species succumbed to the rotenone in direct relation to their size, the smaller ones dying first. This was not entirely due to the behavior of the large fish, which generally fled to the bottom, for small fish died even when seeking refuge in deeper water.

There was also a marked species difference in susceptibility. Of the fishes observed dying from chemical treatment, susceptibility to the rotenone is rated as follows, with the most susceptible species first:

1. Rainbow-steelhead trout;
2. Tule perch;
3. Hardhead;
4. Sacramento squawfish;
5. Smallmouth bass;
6. Roach;
7. Western sucker;
8. Three-spined stickleback;
9. Hitch;
10. White catfish;
11. Carp.

Recovery was noted only among the carp.

Literature regarding the effects of rotenone upon man has, in the past, dealt only with lake treatment, where exposure to the chemical, although severe, has been limited to only one or two days. In this project, personnel were exposed more or less continuously for periods up to three weeks. Symptoms of rotenone poisoning similar to allergic reactions were observed. Headache, sore throats, and other cold symptoms were the primary complaint. In addition, sores developed on mucous membrane areas. The skin wherever moist from perspiration, broke out in an eczema-like rash. This was most prominent in areas such as under the arms and where the clothing was tight, as at the neck and wrists. This was followed by a sloughing of the skin and resulting tenderness. Eyes were also severely irritated and inflammation lasted for a week or more. Loss of appetite and inability to taste accompanied the other symptoms. It is possible that protective devices might be found which would prevent some of the symptoms. In the future, preference could be given to newer forms of the chemical as, for example, wettable rotenone powder or paste, or emulsifiable rotenone in liquid form. Emulsifiable rotenone has the additional advantage of better dispersal. The increased safety and health of the personnel should warrant the higher cost of these newer products.

ACKNOWLEDGMENTS

Acknowledgments are due the many California Department of Fish and Game employees who assisted with the chemical application and electrosampling at various periods throughout the project. Special thanks should go to the host of sportsmen and ranchers who contributed their labor, interest, and cooperation. We are indebted to the City of Santa Rosa and to the Pacific Gas and Electric Company for their cooperation in controlling water releases for us.

SUMMARY

Nearly half the Russian River drainage system in Mendocino and Sonoma counties, California, was treated chemically to control rough fish and improve the steelhead fishery. This form of management was chosen because it was believed that rough fish were affecting the fishery adversely. There was little precedence for chemical control of rough fish in streams on this scale, so the project was largely experimental in nature.

The operational phases of the project took place over a three-year period from 1952 to 1954, inclusive, and included pretreatment population sampling and rechecking immediately following treatment. A total of 286 miles of stream, covering the tributaries and most of the main

river, was chemically treated at an estimated cost of approximately $6,000, or $20 per mile. Slightly more than 9,720 pounds of cubé powder were applied.

Twenty-nine species of fishes, including two lampreys, were observed following the treatment. From counts of dead fish it was estimated that the population in the drainage during the summer consisted of less than 1 percent game fish. The dominant rough fish was the Western sucker, representing 90 percent of the total. Roach, carp, and squawfish ranked second, third, and fourth in the population check. Salmonids, most of which were juvenile steelhead, were scarce except in the headwater areas of the tributary streams. Other game fish, of which the smallmouth bass was the most prominent, were so scarce that they could hardly provide a fishery. Observations following chemical treatment indicated an almost complete kill in the treated areas.

Electrosampling in 1955, the first year after treatment, indicated that at least temporary benefits were derived from the project. The sampling, which was largely restricted to the tributary streams, showed that the juvenile steelhead population increased about 13 times, while at the same time the rough fish population was drastically reduced.

Future work will consist of an extensive sampling program and creel checks to evaluate the work in terms of benfits to the steelhead fishery. The economic feasibility of the project should be revealed by the permanency of the increase of game fish and the rate of recovery of the rough fish population. This part of the project may require as much as eight years.

TWO NEW BLOOD FLUKE PARASITES OF TROUT[1]

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A severe epizootic in Kamloops rainbow trout (*Salmo gairdnerii kamloops*) and steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) occurred in 1955 at the California Department of Fish and Game's Darrah Springs Hatchery, Tehama County, California. Approximately 300,000 fish of these two subspecies were lost, and study showed that the mortality was caused by blood flukes situated primarily in the gills. Subsequent work disclosed a second undescribed species of fluke and a considerably larger area of infection.

Because these blood flukes are small and not easily differentiated from the host tissue, their presence is often overlooked. It seems probable that more species will be described as helminthologists search for them. The extent of their harm is known in only a few cases.

Members of the digenetic trematode family, Sanguinicolidae, are relatively small, approximately one to three millimeters in length. The known species all inhabit the circulatory system of vertebrates and are commonly called blood flukes. They lack true suckers and are without a true pharynx. The esophagus is long and slender and terminates in a lobed "intestine" or "caecum," which is usually X- or H-shaped. The male and female genital pores are separated and located in the posterior portion of the body. The eggs are without an operculum and are tricornered, oval, or subspherical in the known species. These eggs are deposited in the circulatory system and drift to the site of further development. In those cases where a fish is the definitive host, the miracidia escape by way of the gills and eventually enter a snail. The cercariae return to the fish from the snail without requiring a second intermediate host in the known species.

Schäperclaus (1954), speaking of *Sanguinicola inermis* in Germany, says, "The eggs can be present in such a large number that they clot the gill capillaries, bring about thrombosis and lead to death of the fish. In the large ponds of the Peitz fishery I have observed, by the end of July, a great loss among the 6 cm. long carp brood infested with *Sanguinicola* eggs. Large masses of *Sanguinicola* eggs could be found in the gills and kidneys of small carp. . . . Through the infestation by a large number of *Sanguinicola* eggs (15 to 30 eggs were counted in a gill surface of 1 sq. mm.), the gills had been destroyed to a large degree, appeared pale, and showed light spots in numerous places."

Davis (1953) states, "Recently I found an undescribed species of blood fluke infesting the gills of rainbow and cutthroat trout fingerlings

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at an Oregon hatchery (Alsea River, Benton County). The minute adult worms occur in the gill arteries and produce great numbers of eggs, which develop in the capillaries of the gills. All stages from the egg to the fully developed miracidium are found in the gills, and when the flukes are abundant they may cause injuries so extensive that they result in the death of the host. The fish apparently suffer the most serious injury when the miracidia leave the gills, since the greatest mortality occurs at that time." This was the first record from a salmonid and the third record of blood flukes in North American freshwater fishes. It has not been determined whether the fluke, which Davis briefly mentions, is the same as the one here described as *Sanguinicola davisi*. The other two blood flukes were recorded by Van Cleave and Mueller (1932) from *Stizostedion vitreum* and by Fischthal (1949) from *Huro salmoides* and *Micropterus dolomieu dolomieu*.

At the Klamath Hatchery, Klamath County, Oregon, in 1957 a lot of 5,000 Lahontan cutthroat trout fingerlings *(Salmo clarkii henshawi)* was killed by a blood fluke which is here described as *Sanguinicola klamathensis*.[2]

The writer wishes to credit Harold Wolf, Parasitologist of the Department of Fish and Game, for his part in this investigation. His help in identfying *S. davisi* was most important.

DISTRIBUTION OF BLOOD FLUKES

The geographic distribution of the two species of *Sanguinicola* described in this paper is presumably limited by their intermediate hosts, the snails *Oxytrema* and *Fluminicola*. *Oxytrema* is distributed in flowing waters from about San Francisco Bay northward through Washington and into British Columbia. It is abundant in many coastal streams and rivers but has not been found in waters of the interior drainage.

Presumably more than one species of the genus *Oxytrema* can serve as the intermediate host of *Sanguinicola davisi*, but the snails which occur abundantly at the important sites of infection in northern California are *Oxytrema (Goniobasis) circumlineata*.[3] These are not all of the same subspecies but until further taxonomic work has been done on this genus of snails it seems best to avoid the use of trinomials. In the Alsea River, Benton County, Oregon, the species is presumed to be *Oxytrema silicula*.[4] Probably this is the intermediate host of the fluke described by Davis.

In the case of the second new species of blood fluke, *Sanguinicola klamathensis*, from the Klamath Hatchery, Oregon, the intermediate host snail is presumed to be *Fluminicola seminalis*.

Eggs of a blood fluke, presumably some species of *Sanguinicola*, were found in 1957 in steelhead rainbow fingerlings in the Oakridge Salmon Hatchery on the Middle Willamette River, Marion County, Oregon. The snail involved is not known.

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[2] The writer wishes to thank Dr. H. J. Rayner, Chief of Operations of the Fishery Division, Oregon State Game Commission, and R. A. Evans of the Klamath Hatchery for material used in this study.

[3] This snail and the two from the Klamath Hatchery were kindly identified by Allyn G. Smith, Research Malacologist of the California Academy of Sciences.

[4] I follow Dr. Ivan Pratt and coworkers at Oregon State College with respect to the identity of this population of *Oxytrema*.

The heavy mortalities suffered by kamloops and steelhead rainbow at the Darrah Springs Hatchery led to a survey of trout, both in hatcheries and in the wild, throughout a large part of California. This survey clearly indicated that the range of fish parasitized by *S. davisi* coincides with the range of the snail *Oxytrema*. In a few localities, fish whose gills contained eggs of the blood fluke were found in waters where the snail may not exist, but in all these waters infected hatchery trout had recently been planted. Therefore, we have good reason to believe that the natural distribution of *S. davisi* is limited to the range of *Oxytrema*.

A particularly clear-cut instance of this relationship was found in the Russian River drainage of Sonoma County, California. Steelhead fingerlings collected in Warm Springs Creek on the west slope of the drainage showed a high incidence of parasitization and in this stream *Oxytrema* was moderately abundant. Maacama Creek flows into the Russian River from the east slope of the drainage and from this stream many steelhead fingerlings were collected, but none was found to contain the fluke, nor was the snail *Oxytrema* present in this stream.

At the Darrah Springs Hatchery there are two groups of springs. These form two streams, which eventually flow together. One of these streams lies within a ranch and livestock commonly wade in the stream and eat the water cress (*Radicula nasturtium-aquaticum*). Presumably because the cress is eaten and the water made turbid by the disturbed silt, the snail population is sparse. In the hatchery ponds supplied from this stream the trout have significantly fewer blood flukes than do those in the ponds supplied by the second stream. This second stream lies entirely within the hatchery property and so has no livestock to control the snail population.

The numbers of *Oxytrema* are governed by several factors. Perhaps most important are water chemistry, aquatic plants, and the physical geography of the stream. These factors, and perhaps others, seem to be important, but the relative value of each is unknown. It is generally assumed that the water must contain calcium in some form, although water analyses from Warm Springs Creek and Maacama Creek did not show a great difference in this respect. Also, the Mt. Shasta Hatchery water supply is relatively low in calcium, but has a very heavy snail population. It would seem, therefore, that calcium alone is not the limiting factor. Aquatic plants, particularly water cress, seem to be correlated with the highest densities of *Oxytrema*, but this is true only within the range of the snail and, of course, great numbers of spring-fed streams with abundant water cress have no *Oxytrema*. In brief, we do not know completely the factors limiting the distribution of *Oxytrema*. All we can say is that within the range of the snail, those spring-fed streams containing abundant water cress usually have great numbers of the snail. In addition, we know that where many *Oxytrema* are present, susceptible species of trout show considerable numbers of *Sanguinicola*.

The distribution of the second species, *Sanguinicola klamathensis*, is at present known to be the Klamath Hatchery on Crooked Creek, Klamath County, Oregon. The snail which is presumably involved lives in a spring-fed reservoir on the hatchery grounds. There are two species of snails in this small reservoir, *ParaphOlyx effusa* and *Fluminicola seminalis*. Two types of cercariae were found in the latter snail, one a lophocercous furcocercous type (Figure 1), which is presumed to be *S. klamathensis*.

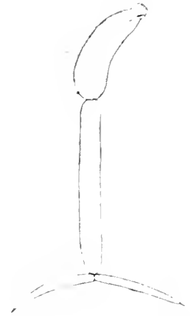


FIGURE 1. Cercaria of *S. klamathensis* from the snail *Fluminicola seminalis*. Note body keel and claws on caudal forks. Total length 0.98 mm. From Klamath Hatchery, Oregon, March, 1957.

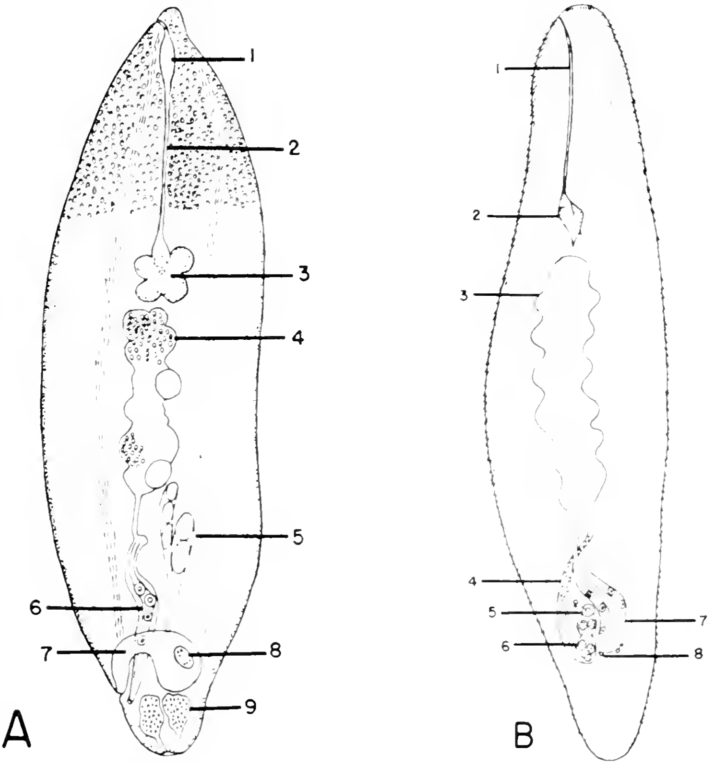
THE LIFE CYCLE

Relatively little is known about the cycle of *S. klamathensis*, whereas that of *S. davisi* is more completely understood. Therefore, in the following discussion the features of the *S. klamathensis* cycle will be mentioned only when they seem to differ from those of *S. davisi*.

The adult fluke (Figure 2) of *S. davisi* normally resides in the main gill capillary, which lies parallel to the cartilaginous gill arch. Thus, in dissecting out the adult flukes of this species one must break the arch and the blood vessel. When this is done the fluke will emerge. Occasionally the adult fluke will be found in a subcapillary extending out into a gill filament. The diameter of the adult fluke is almost too great to allow it to live in the filament capillary of a fingerling trout, but in the main capillary it can crawl back and forth quite freely. The writer has not found the adult fluke of this species in any part of the circulatory system outside the gills. In this respect *S. klamathensis* is quite different. Here the adult fluke (Figure 2) is usually situated in the efferent renal vein. When the fish is dissected and the viscera are removed, the fluke can be seen crawling freely back and forth in this vessel, where it is exposed on the ventral surface of the kidney.

The adult *S. davisi* produces but one egg at a time, whereas *S. klamathensis* may have several mature eggs in the ootype at one time. After the eggs are expelled, in either species, they presumably drift with the blood to the capillaries of the gill filaments, where they lodge. Eggs of *S. davisi* can be found in stages from a simple sphere to the mature miracidium (Figures 3 and 4). When the miracidium approaches maturity, the cilia begin to beat. Eventually the miracidium works through the epithelium to the surface of the gill filament and produces a lobule. The lobules have been seen to break, setting free the miracidia, which swim away actively.

It is assumed that the miracidium now contacts and enters an appropriate snail, a species of *Oxytrema* in the case of *S. davisi* and presumably *Fluminicola seminalis* in *S. klamathensis*. In the case of *S. davisi* it was found that little more than 2 percent of the snails in the Mt. Shasta Hatchery water supply were infected. These contained large numbers of sporocyst and redia stages of the fluke.



A B

FIGURE 2. Adult blood flukes. **A,** *Sanguinicola davisi* from main gill capillary of rainbow trout collected at Mount Shasta Hatchery in 1956. Total length 0.85 mm. 1, pharynx; 2, esophagus; 3, intestine; 4, testes; 5, ovary; 6, cirrus sac; 7, ootype; 8, capsule; 9, protonephridia. **B,** *Sanguinicola klamathensis* from the efferent renal vein of cutthroat trout fingerlings collected from Klamath Hatchery, Oregon, in 1957. Total length 2.67 mm. 1, esophagus; 2, intestine; 3, testes; 4, oviduct; 5, female gonopore; 6, capsule; 7, cirrus sac; 8, male gonopore.

The length of time required for the development of cercariae is not known, but eventually they emerge from the snail and swim off in a characteristic jerky, writhing motion.

Rainbow trout fingerlings were exposed experimentally to the cercariae, believed to be *S. davisi*, found in the snails at the Mt. Shasta Hatchery. Within a few minutes these had penetrated the tissue of the fins, had dropped their tails, and were active within the vascular cavities lying between the fin rays. They appeared to move about within the tissue of the host by use of the spined head, which they can extend and withdraw. It was not demonstrated experimentally but is assumed that the flukes in this stage move through the blood vessels to the main gill arch capillary, where they complete their development.

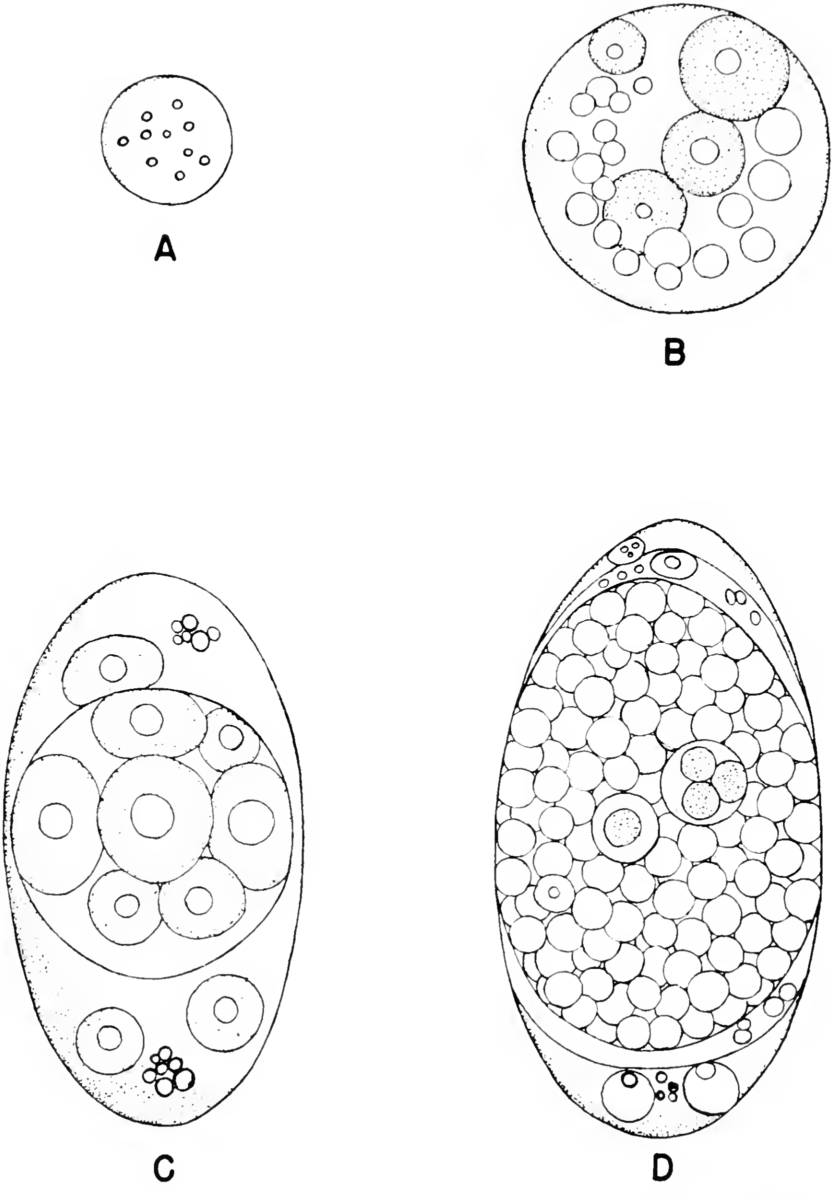


FIGURE 3. Early stages of *Sanguinicola davisi* from the gills of rainbow trout collected from Darrah Springs Hatchery in 1956. **A,** egg (16.6 μ); **B,** developing egg (13 μ); **C,** developing embryo (37 μ); **D,** later stage of embryo development (35-63 μ).

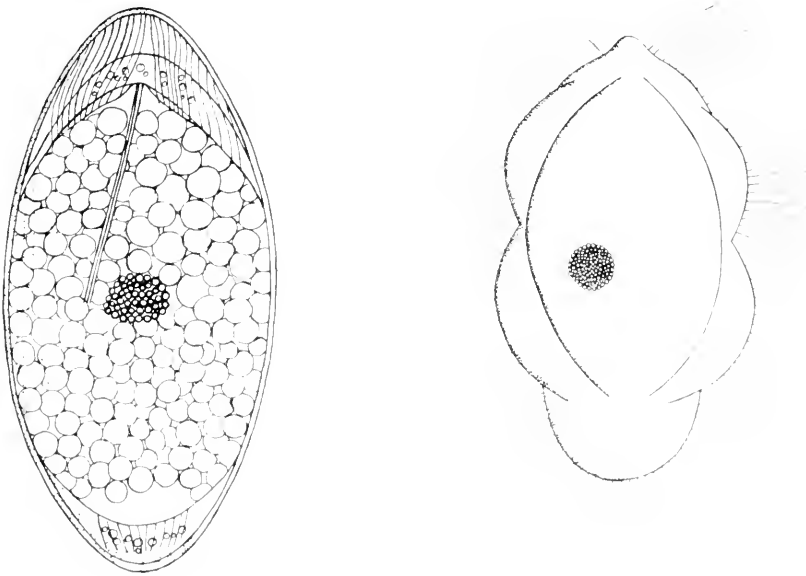


FIGURE 4. **A,** developing miracidium of *S. davisi* (30-56 μ). Cilia start to beat at this stage. Note black eye spot. From gills of rainbow trout collected in 1956 at Darrah Springs Hatchery. **B,** free-swimming miracidium of *S. davisi* (58 μ) from gills of rainbow trout collected at Darrah Springs Hatchery, January 23, 1956.

PATHOLOGY

Despite large numbers of observations on infected trout at several hatcheries and in wild populations, the effect of this parasite upon the fish is little understood. It has been pointed out that Schäperclaus (1954) believes that the eggs inhibit circulation in the gill capillaries. It is difficult to show experimentally the degree of respiratory embarrassment suffered by heavily infected fish, but the writer believes that it may be considerable. In advanced cases the filaments are pale and flaccid and may be so filled with eggs that under the microscope half of the total gill volume appears to be composed of fluke eggs. It is conceivable that when large numbers of miracidia emerge, the loss of blood is lethal. Even though the numbers and volume of eggs and adult flukes may be so great that it is difficult to believe such infected fish can live, in most instances the fish are surprisingly normal in appearance. They may be more or less weakened and their growth may be reduced, but it has been found that when these fish are moved to an uninfected water either the eggs mature and leave the gills or they degenerate and the gills eventually recover.

Although the gills are usually the only tissue infected with eggs or adult worms, steelhead rainbow trout fingerlings at the Mt. Shasta Hatchery were found to have some fluke eggs in their kidneys. In the case of *S. klamathensis* the adult fluke may occasionally inhabit the bulbus arteriosus, although the efferent renal vein is the usual site.

TAXONOMY

Hyman (1951) differs considerably from Yamaguti (1953) in the systematic arrangement of the known species of the family Sanguinicolidae. Hyman believes the family should comprise the single genus *Sanguinicola*, with the species *chalmersi*, *inermis*, *intermedia*, and *occidentalis*. Yamaguti, on the other hand, includes in this family with the type genus the genera *Deontacylix* (*D. ovalis*), *Psettarium* (*P. japonicum* and *tropicum*), and *Paradeontacylix* (*P. sanguinicoloides* and *odhneri*).

The fluke found in the northern California trout hatcheries and herein named *Sanguinicola davisi*, in honor of H. S. Davis,[5] agrees in general with the generic description given by Yamaguti. It differs with respect to the shape of the egg, which is oval in *davisi* but has lateral projections in the other species in which the shape of the egg is known. This might be considered of enough importance to warrant erection of a new genus, but the writer would prefer to leave it in *Sanguinicola* for the present and simply modify the generic description. The fluke being described does not belong in the genus *Deontacylix*. The esophagus is straight rathen than sinuous. The intestine is roughly X-shaped, not H-shaped, with the posterior rami extending to the equator. Neither does this fluke belong to the genus *Psettarium*, since it lacks a "conical dorsal projection near posterior right margin and a distinct marginal notch immediately in front of it". Nor do the posterior rami of the intestine extend into the posterior half of the body. *Sanguinicola* differs from *Paradeontacylix* in the shape of the body. In *Sanguinicola* it is spindle-shaped, whereas in *Paradeontacylix* it is slender and uniform in breadth. Also, the rami of the intestine do not extend into the posterior half of the body.

DESCRIPTION OF *SANGUINICOLA DAVISI* N. SP.

The adult fluke is about 8.5 mm. long and about 0.21 mm. in greatest width. The body is spindle-shaped, moderately flattened, with columns of spines in three or four rows along each edge extending almost but not entirely to the anterior and posterior ends of the body. There are no spines of any size on the remainder of the body. The anterior end terminates in a poorly defined proboscis, which is covered with very small spines arranged in whorls. The mouth is subterminal, opening just posterior to the proboscis. The tip of the pharynx has three spine-like projections. The pharynx is fusiform and poorly developed. The esophagus is straight and narrow, expanding as it enters the caecum. The caecum is roughly X-shaped, with four short lobes. The testes are massive, irregular, with the sperm duct terminating in an expanded, crooked, thick-walled cirrus sac. The male gonopore is posterior to the female gonopore but near it. The ovary is bilobed, with the oviduct entering the side of the gourd-shaped ootype. Only one egg is present in the ootype. The protonephridia are poorly defined; their exact structure has not been determined. The entire body is filled with yolk gland.

The cercariae (Figure 5) of *S. davisi* are similar to those of *S. inermis*, except in that in *davisi* the keel or body fin is lacking. The tail is

[5] Fish pathologist formerly In Charge, Agricultural Investigations, U. S. Fish and Wildlife Service, and author of "Culture and Diseases of Game Fishes".

forked and the forks are tipped with delicate spheres. The body is moderately curved. There is a proboscis armed with rows of fine spines. The oral opening is just posterior to the spinous proboscis. The anterior end of the esophagus is similar to that of the adult fluke, apparently with three spine-like projections. The pharynx is moderately swollen just behind the tip and then becomes a straight, narrow esophagus ending in a four-lobed intestine, which is quite similar to that of the adult. The dimensions of the cercariae of *S. davisi* are: body 0.23 x 0.056 mm.; tail 0.34 x 0.035 mm.

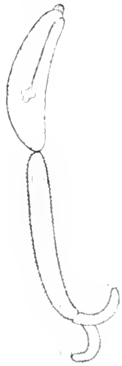


FIGURE 5. Cercaria of *S. davisi* from the snail *Oxytrema circumlineata*, collected at Mount Shasta Hatchery on June 12, 1956. Note the lack of a body keel and the presence of spheres on the caudal forks.

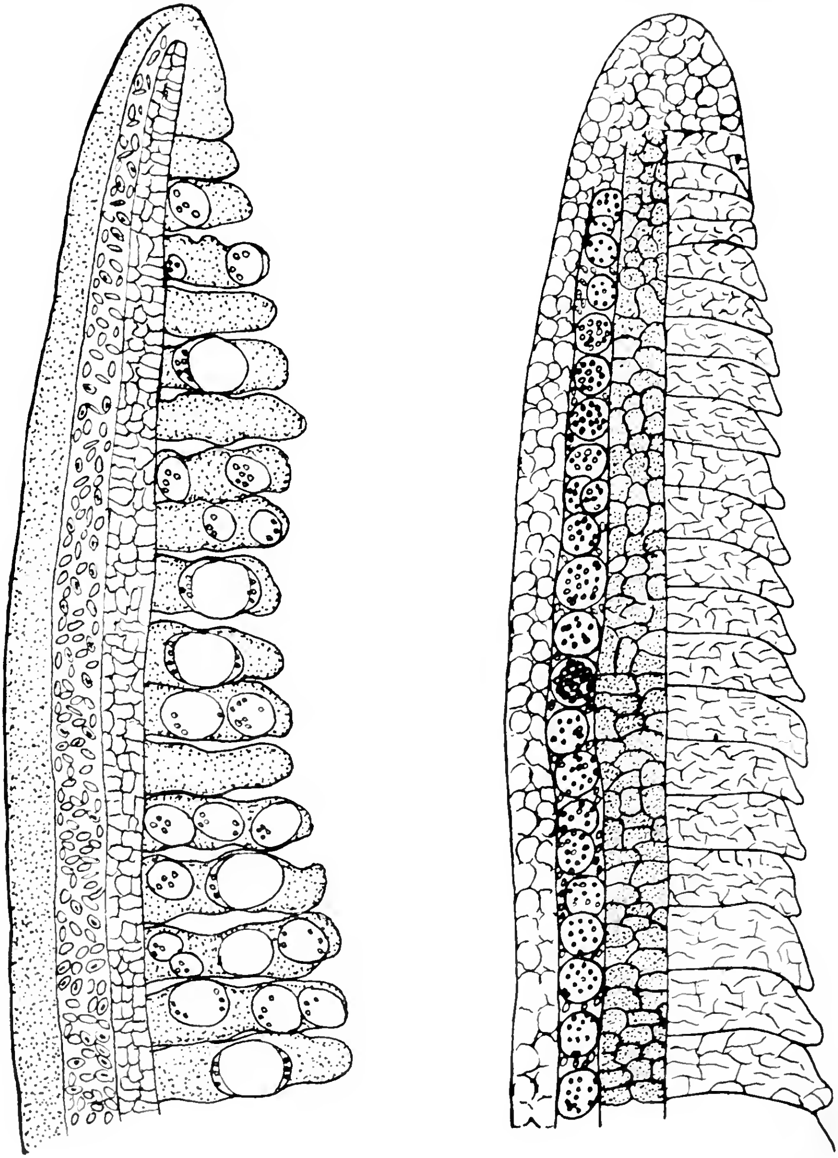
The earliest embryonic stages to be found in the gills of infected trout are simple spheres measuring about 16-17 μ in diameter and containing a few small globules (Figure 3A). This spherical stage gradually enlarges and becomes increasingly more oval (Figure 3C), eventually reaching a length of 65-70 μ before the miracidium is fully developed. The jet black "eye spot" is a distinctive characteristic of the developing miracidium, although it is not peculiar to this one species. It is composed of a small, irregular cluster of spherical melanin granules. Long before the miracidium emerges, the cilia can be seen beating. Finally, when it is fully developed the miracidium, in its oval case, reaches the surface of the gill filament and forms a lobule. It then breaks out of the case and through the gill epithelium and swims off in a rapid and erratic manner.

DESCRIPTION OF *SANGUINICOLA KLAMATHENSIS* N. SP.

The lengths of four adult flukes from the efferent renal vein of four Lahontan cutthroat trout fingerlings were: 2.45, 2.67, 2.76, and 3.15 mm. The one which was 2.67 mm. long was 0.91 mm. broad. The body is spindle-shaped, with two longitudinal columns of heavy spines extending nearly the length of the body. In addition to these heavy spines, the body is covered with very small spines. The proboscis is moderately developed, with about eight whorls of small spines. The mouth is just posterior to the proboscis. The tip of the esophagus is apparently armed with three curved projections, as in *S. davisi*. There is no pharynx-like enlargement of the esophagus. The esophagus is straight and slender, ending in an unsymmetrical sac-like intestine. The exact shapes of the ovaries and testes were not determined. The male gonopore lies posterior to the female gonopore. The oviduct connects with the posterior end of the ootype, and the latter may contain several eggs, not just one (as in *S. davisi*).

Two types of cercariae were found in the snail *Fluminicola*. One was of the lophocercous furcocercous type (Figure 1), closely resembling that of *S. inermis*, and it is assumed that this is the one belonging to *S. klamathensis*. The total length of these cercariae is about 0.98 mm.

The anterior portion of the head is separated from the posterior part by a ring-like constriction. At the anterior end of the head there are about six concentric rows of short, heavy spines. Posterior to these heavy spines there are some delicate, more widely-scattered bristles. The



A B

FIGURE 6. **A,** gill filament of a rainbow trout collected from Mount Shasta Hatchery in 1957, showing the relative size and locations of embryonic states of *S. davisi;* **B,** gill filament of a cutthroat trout collected from Klamath Hatchery, Oregon, March 29, 1957, showing the relative size and locations of *Sanguinicola klamathensis* eggs in the main capillary.

oral aperture lies just posterior to the spinous portion of the head, in the same relative position as in *S. davisi*. The body keel is very delicate and extends little more than half the length of the head of the cercaria. The forks of the tail are tipped with claw-like projections, rather than with spheres (as in *S. davisi*).

The eggs of this blood fluke are apparently unique among the known species of this genus. Most of the species in which the shape of the egg is known are tri-cornered. In *S. davisi* they are oval except in the very early stages. In *S. klamathensis* the eggs are spherical or subspherical in all the stages observed. This species also differs from *S. davisi* in the location of the eggs within the gills. In *S. davisi* they usually occur in the capillaries of the secondary lamellae, whereas in *S. klamathensis* they lodge in the main capillaries of the filaments, forming bead-like rows when they are abundant (Figure 6).

The systematic position of *S. klamathensis* is somewhat doubtful. It is placed in the genus *Sanguinicola* with reservations. In *S. klamathensis* the ootype may have several eggs, rather than just one. In both *S. davisi* and *S. klamathensis* the eggs are oval or spherical and never with lateral projections. In *S. klamathensis* the intestine is neither X-shaped nor five-lobed. In *Deontacylix* the shape of the eggs is more nearly like that in *S. klamathensis*; however, there are major differences. There seems to be little reason for thinking that *S. klamathensis* could be referred to the genus *Paradeontacylix*. The writer believes that for the present, at least, a new genus should not be erected and that the description of the type genus *Sanguinicola* should be broadened to encompass both *klamathensis* and *davisi*.

CONTROL METHODS

The only known method of control of these blood flukes is the removal of either the snails or the fish. The removal of wild rainbow or cutthroat trout from the hatchery water supply would break the life cycle. Eastern brook *(Salvelinus fontinalis)* and brown trout *(Salmo trutta)* are not susceptible to these flukes, insofar as is known.

In some cases the water supply stream or ditch could be reconstructed to provide less habitat for snails.

Chemical treatment of a water supply to eradicate the snails without harming the fish in the hatchery is also a possibility, although to date no adequate treatment has been found.

SUMMARY

A severe epizootic at the Darrah Springs Hatchery of the California Department of Fish and Game in 1955 is believed to have been caused by a blood fluke. This very small, digenetic trematode was found in the gill capillaries of steelhead and kamloops rainbow trout and subsequently has been found in domesticated rainbow in two other northern California hatcheries. This adult fluke is less than one millimeter in length. It produces great numbers of eggs, which lodge in the capillaries of the secondary lamaellae and interfere with respiration. The eggs eventually develop into the miracidium stage and the miracidia break out through the gill epithelium and swim away. This rupture of the capillary walls results in a loss of blood.

Presumably the miracidia, after leaving the trout, enter a snail and continue their development in the snail until the cercaria stage is reached. The cercariae have been observed in this investigation to leave the snails in large numbers and to penetrate the fins of trout fingerlings. It is assumed that they migrate through the circulatory system to the gills and complete the life cycle.

Eggs of the blood fluke have been found in abundance in wild steelhead fingerlings, only recently emerged from the gravel, and in all ages of rainbow up to mature fish of 15 inches in length. However, they seem to be most abundant in fish less than a year old and less than eight inches in length.

Two species of blood flukes have been found during the course of this study; both of them are here described as new. The more common one, *Sanguinicola davisi*, is abundant in three northern California hatcheries and appears to occur in wild steelhead within the range of the snails of the genus *Oxytrema*. The second species of fluke has been found only in southern Oregon. This fluke has been named *Sanguinicola klamathensis* and was found in Lahontan cutthroat trout fingerlings. The intermediate host of this fluke is the snail *Fluminicola seminalis*.

The only known control method is the removal of either the snails or the fish. The removal of wild rainbow or cutthroat trout from the hatchery water supply would break the life cycle. Eastern brook and brown trout are not susceptible to these flukes, insofar as is known.

In some cases physical alteration of the hatchery water supply would provide less habitat for snails.

A satisifactory chemical treatment of hatchery water supplies to eradicate snails without harming the fish in the hatchery has not yet been found.

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A REVIEW OF THE EASTERN PACIFIC SHARKS OF THE GENUS *CARCHARHINUS*, WITH A REDESCRIPTION OF *C. MALPELOENSIS* (FOWLER) AND CALIFORNIA RECORDS OF *C. REMOTUS* (DUMÉRIL)[1]

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Carcharhinus is the largest single genus of modern sharks, being represented in warm seas by a large number of species. Recent investigations of the California Department of Fish and Game, utilizing experimental tuna longline gear, indicate that sharks of this genus are abundant at a number of localities south of the Mexican-American boundary. For example, at a Clarion Island station a set of 550 hooks resulted in the capture of 69 individuals of various species of *Carcharhinus* (Harold Clemens, personal communication). Only 11 other sharks of all other genera were taken.

This large eastern Pacific population of sharks represents an untapped resource of considerable potential value. In the Caribbean an important shark fishery has been developed, the catch being utilized in the production of fertilizer and leather, as well as food for human consumption. Although sharks have been little exploited in the eastern Pacific, except for the production of liver oil, there appears to be no reason why a successful shark fishery could not be developed here.

The direct commercial value of these sharks may be overshadowed by their indirect effects on populations of economically important species. It is likely that some species of *Carcharhinus* compete directly for food with such fishes as tuna and skipjack. The possibility also exists that predation by sharks may operate as a factor limiting population size in these and other species. Until adequate life history information is available, the impact of shark populations on other commercial species will remain an unknown quantity. Work of this nature cannot be undertaken unless the fishery biologist has adequate taxonomic studies available to him, since food habits, behavior, fecundity, growth rate, and maximum size vary widely from species to species. It is hoped that the present work, in providing a basis for further investigations, will be helpful to the fishery biologist as well as to the systematist.

Although the species of *Carcharhinus* differ widely in many respects, the genus is readily separable from all other genera of carcharhinid sharks by the following combination of characters: second dorsal and anal bases about equal in length; second dorsal much smaller than the first; first dorsal inserted close to inner angle of pectoral; labial furrow

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of upper jaw very short; spiracles lacking; teeth in upper jaw about 30 in number, cusps serrate.

Specimens of *Carcharhinus* are poorly represented in collections, since most of the species are large. As a consequence, most species have been described from juveniles or late embryos. It is unfortunate that adults are usually simply discarded, since good identifications can be made from fragments, together with certain photographs. The jaws, or the head cut off behind the first gill slit, and the tail section removed just in front of the second dorsal and anal origins, in combination with a full length photograph, are usually sufficient for identification. If no portion of a large individual can be preserved, a full length photograph, together with close-ups of the underside of the head and the tail section, including the second dorsal and anal fins, as well as the caudal, will often suffice. Skin samples (taken directly below the first dorsal) and the claspers of adult males are not always necessary for identification, but may prove important in determining relationships.

Many of the eastern Pacific species of *Carcharhinus* resemble each other closely and have been repeatedly confused, so that a number of published records are doubtful. This is particularly true of records based on jaws or teeth alone. While it is true that tooth characters are important in the classification of these sharks, the diagnostic value of such features as shape and relative coarseness of serration of the teeth has been greatly overemphasized. Although it is possible to set off groups of *Carcharhinus* by using tooth shape, it is almost impossible to make a positive identification based on tooth characters alone.

In our investigation we have been able to examine specimens of all the eastern Pacific species. It has proved possible to construct a workable key, based on characters which are constant for a species. Those characters subject to interpretation have been illustrated with semi-diagrammatic line drawings, one representing the species in question, the other the species most likely to be confused with it. Following the key, a diagnosis and a discussion of identification and special problems are given for each species. The diagnoses are presented primarily as aids to identification, although an attempt has been made to include noncontrasting characters which may be of value in determining relationships. Proportions given in the diagnoses are modal values for the species under consideration. The brief synonymies are restricted to a citation of the original description and eastern Pacific synonyms, and are not intended to be complete. More complete synonymies may be found in Beebe and Tee-Van (1941) and Bigelow and Schroeder (1948). Each diagnosis and discussion is followed by a list of materials examined. Unless otherwise specified, all material is deposited in the fish collection, Department of Zoology, University of California, Los Angeles.

All measurements used herein are straight line measurements between two points. All proportions were stepped off with needlepoint dividers. Although most of the measurements correspond to those defined by Hubbs and Lagler (1947), a number of nonstandard measurements have been incorporated. Most of these are self explanatory; those which are not are illustrated in Figure 1.

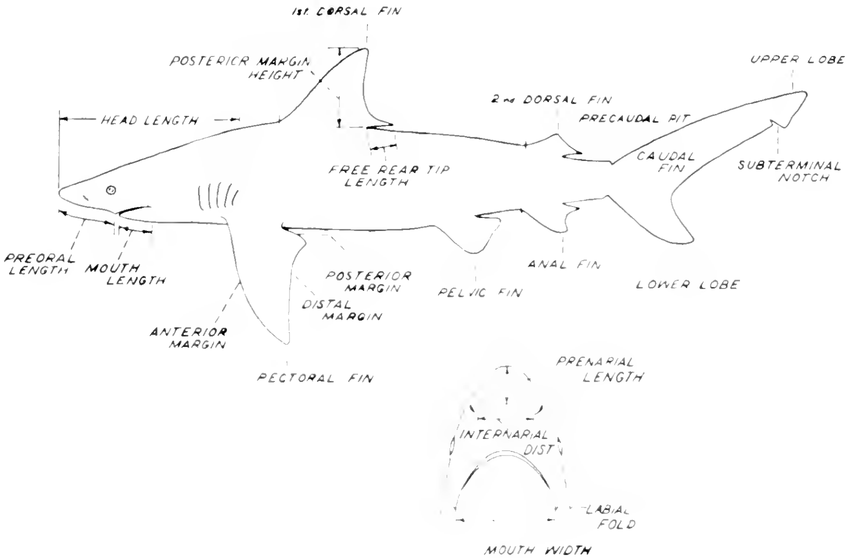

FIGURE 1. Topography of a *Carcharhinus*, illustrating how certain measurements are to be made, and locating certain features used in identification.

Since the key and diagnoses are based on specimens in the one-meter size range, it is likely that large adults will present a problem in identification. It is probable that as size increases the body tends to become deeper, the head broader, and the fins longer and more pointed.

Certain specimens in the collection at the University of California, Los Angeles, appear to be referable to the little known species *Carcharhinus malpeloensis* (Fowler, 1944). Fowler's description was based on two embryos collected at Malpelo Island, Colombia; the species has not been reported since. Although the description offered by Fowler is sketchy, and his figure obviously stylized, enough diagnostic features are indicated to make the identification of the specimens at hand relatively certain.

Inasmuch as Fowler's description was based on embryos and is inadequate in many respects, we present a complete redescription of this species, together with a discussion of its affinities. We have adopted the general format of Bigelow and Schroeder (1948) for our description; however, some of our measurements differ from theirs.

SYSTEMATIC ACCOUNT

The description given below was taken from two subadults collected south of Costa Rica (7° 23.8′ N., 86° 29.6′ W.), UCLA55-307, 710 and 1,072 mm. in total length (Figure 2), since our other specimens are late embryos. The condition of the character under discussion is given for both specimens: the first figure refers to the larger specimen, the second (in parentheses) to the smaller. Additional morphometric data are given in Table 1.

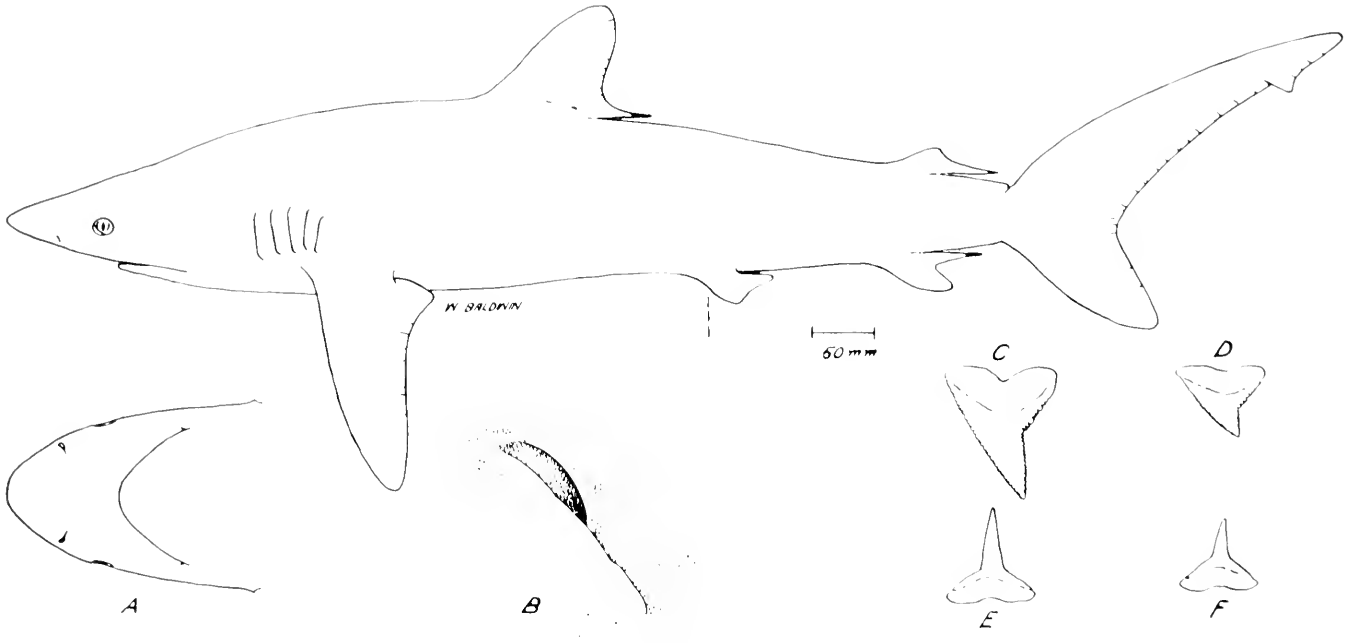

FIGURE 2. *Carcharhinus malpeloensis.* UCLA56-307, 1,072 mm. total length. A, underside of head; B, detail of nostril; C, 4th tooth of upper jaw; D, 11th tooth of upper jaw; E, 4th tooth of lower jaw; F, 11th tooth of lower jaw.

Carcharhinus malpeloensis (Fowler)

Trunk moderately slender, height at origin of first dorsal 5.2 (6.2) in length of body without caudal fin, width of trunk at origin of first dorsal 6.8 (7.1) in length without caudal. Midline of back with a definite dermal ridge extending from rear tip of first dorsal to a point about 2.5 eye diameters in front of second dorsal origin. Upper precaudal pit well developed, crescent-shaped; lower precaudal pit weakly developed, crescent-shaped. Head 3.0 (2.7) in length without caudal, considerably narrower at eyes than at origin of pectorals, ¾ as wide at outer margin of nostrils as at eyes. Snout narrowly rounded, its length from a line connecting the outer ends of the nostrils 1.7 (1.7) into preoral distance. Preoral length 3.2 (2.8) into head length. Eye nearly circular, horizontal diameter slightly greater than vertical diameter, the fleshy orbit 3.3 (2.9) in internarial distance, 2.0 (1.4) in first gill slit. Third gill slit longest, fifth gill slit 1.3 (1.5) in first gill slit, second and third gill slits almost equal, slightly longer than fourth. Gill slits evenly spaced, fourth and fifth slightly closer together, base of third gill slit over pectoral origin. Nostrils slightly oblique, a line between inner ends of nostrils closer to mouth than to tip of snout by a distance equal to 1.5 (1.3) eye diameters. Anterior margin of nostril slightly expanded toward inner end into a slight lobe. Mouth ovate, its length 1.7 (1.7) in its width. Mouth width about equal to preoral distance. First dorsal low and rounded, the angle of its posterior margin with the back obtuse, its height 0.7 (0.8) in preoral distance, height of posterior margin 1.6 (1.5) in vertical height. Free rear tip of first dorsal relatively long, 2.5 (2.7) in both vertical height and height of posterior margin; 1.6 (1.6) in length of pectoral. Origin of first dorsal posterior to the inner corner of pectoral by a little more than one eye diameter. Length of base of first dorsal 1.3 (1.3) in height; a little less than twice as long as length of free rear tip. Origin of second dorsal slightly behind anal origin. Base of second dorsal about ⅓ as long as base of first dorsal and about ¾ as long as vertical height of second dorsal. Anterior margin of second dorsal slightly convex, posterior margin moderately concave, apex rounded. Free rear tip of second dorsal slender and elongate, extending to about one eye diameter anterior to upper precaudal pit. Vertical height of second dorsal 2.3 (2.4) in length of free rear tip. Anal slightly longer at base than second dorsal, anterior margin convex, posterior margin deeply concave, apex lobe-like, much more rounded than second dorsal. Vertical height of anal 1.4 (1.4) in length of base. Free rear tip long and slender, containing the length of the anal base 1.8 (1.8) times, reaching a point about one eye diameter from lower precaudal pit. Distance from anal origin to tip of pelvics 1.9 (1.8) in anal base. Pelvic origin slightly closer to origin of first dorsal than to origin of second dorsal. Anterior margin of pelvics slightly convex, posterior margin slightly concave. Length of pelvics 2.1 (2.2) in height of first dorsal. Pectorals slightly falcate, anterior margin slightly convex, distal margin slightly concave, posterior margin moderately convex. Tip of pectorals moderately rounded, not pointed. Pectoral length 1.3 (1.5) in head length. Pectorals a little less than twice as long as broad. Caudal length 2.8 (2.7) in length of body without caudal. Upper margin slightly convex, slender and moderately rounded at tip, distance from subterminal notch to caudal tip, (terminal sector) 4.5 (4.7) in length of caudal. Posterior margin of caudal slightly concave. Length of subterminal notch 6.0 (6.4) in length of lower caudal lobe. Ventral margin of lower caudal lobe moderately convex, tip rounded. Length of lower caudal lobe 2.1 (2.4) in length of upper caudal lobe.

Teeth $\left(\frac{16\text{-}1\text{-}16 \quad 16\text{-}1 \text{ or } 2\text{-}16}{16\text{-}1\text{-}16 \quad 16\text{-}1\text{-}15 \text{ or } 16}\right)$, upper center teeth nearly symmetrical, the margins becoming increasingly oblique toward the corners of the jaw, the depth of the lateral notch increasing with the decrease in size of the teeth toward the side of the mouth. Edges of upper teeth finely serrate on cusps, bases more coarsely serrate. All lower teeth symmetrical, cusps smooth.

Dermal denticles overlapping, slightly wider than long. Each denticle with 3 to 5 parallel ridges ending in a short spine, the spine of the outer ridges weak or lacking.

Color of back uniform dark blue-gray, fading into the whitish underside. Upper surfaces of paired fins dark, underside of pectoral dusky (not black) at tip. First dorsal slightly lighter than body, the leading edge darker. Second dorsal similar in color to back. Anal dusky, its base white. Upper lobe of caudal similar in color to back, lower lobe lighter. None of the fins with black margins or black spots.

The embryos resemble the subadults very closely, with the exception that the snout is relatively narrower and more sharply pointed, the fins are shorter, and the tips of all fins tend to be quite dark.

Relationships

According to the key to the western Atlantic Carcharhinidae without spiracles presented by Springer (1950), *C. malpeloensis* fits into the genus *Eulamia*, since a definite dermal ridge between the dorsal fins is present. We prefer, however, to follow recent authors (Bigelow and Schroeder, 1948; Hubbs, 1951) in considering *Eulamia* Gill 1862 to be a synonym of *Carcharhinus* Blainville 1816. In our opinion, the separation of the ridge-backed species from the smooth-backed forms produces taxa which are neither natural nor convenient. As pointed out by Springer (1950) and Hubbs (1951), the presence or absence of a mid-dorsal ridge is often dependent on preservation, much museum material being unreliable in this respect. However, the fact that a character must be used with circumspection, and does not lend itself readily to the construction of keys, need not vitiate its possible validity as an indicator of phylogeny. There is evidence that the mid-dorsal ridge is not, however, a good indicator of phyletic lines within the genus *Carcharhinus*. It certainly does not correlate with other characters such as tooth structure, body and head shape, and fin configuration, which also may be of value in determining relationships. While it is true that most of the New World forms with a mid-dorsal ridge have broadly triangular teeth in the upper jaw, and those with the back smooth usually have teeth with erect triangular cusps, this is not invariably the case. *C. altima*, for example, has a definite dermal ridge, but teeth which are as narrow as those of any member of the smooth-backed group (Springer, 1950). The teeth of *C. malpeloensis*, another ridge-backed species, approach the condition found in most smooth-backs; conversely, the smooth-backed *C. leucas* and *C. nicaraguensis*

TABLE 1

Carcharhinus malpeloensis: Measurements of Body Parts and Proportions in Length Without Caudal

	UCLA55-307 Off Costa Rica				UCLA55-63 Panama		UCLA54-265 Vicinity Islas Revillagigedo	
Sex	♀		♀		♂		♂	
Total length	1072.0		710.0		480.0		499.0	
Length without caudal	782.0		516.0		347.0		343.2	
Trunk width over pectoral origins	132.1	0.169	84.0	0.163	49.8	0.144	51.0	(0.149)
Trunk height at pectoral origins	139.0	.178	75.0	.145	52.6	.152	48.8	(.142)
Head length	269.9	.345	187.6	.364	129.0	.372	121.1	(.353)
Head width at angles of mouth	135.0	.173	86.3	.167	58.0	.167	58.4	(.170)
Interorbital width	108.2	.138	76.5	.148	53.0	.153	53.0	(.154)
Head width at outer ends nostrils	84.0	(.107)	62.1	(.120)	41.9	.121	41.5	(.121)
Mouth width	94.6	(.121)	64.5	.125	38.9	.112	41.5	(.121)
Mouth length	60.0	.077	42.0	.081	28.9	.083	28.2	(.082)
Fleshy orbit diameter	17.0	.022	16.1	.031	10.4	.030	13.1	(.038)
Preoral length	87.3	.112	64.9	.126	44.4	.128	42.9	.125
Prenarial length	45.5	.058	37.2	.072	22.4	.065	22.8	(.066)
Nostril length	15.2	.019	9.2	.018	7.0	.020	7.2	(.021)
Internarial distance	61.5	.079	42.6	.082	30.3	.087	29.2	(.085)
Length labial fold	6.5	.008	6.0	.012	3.7	(.011)	2.6	(.008)
Length 1st gill slit	36.0	.046	20.5	.040	9.5	.027	12.2	(.036)
Length 2d gill slit	38.2	.049	22.0	.043	10.9	.031	12.1	(.036)
Length 3d gill slit	37.9	.048	24.0	.046	11.5	.033	12.9	(.038)
Length 4th gill slit	32.5	.042	22.0	.043	11.4	.033	11.2	(.033)
Length 5th gill slit	28.0	.036	17.5	.034	8.0	.023	10.1	.029
Origin P_1 to base first gill slit	35.9	.046	21.4	.041	16.2	.047	12.6	(.037)
Height first dorsal	131.9	.169	77.8	.151	53.0	.153	52.0	(.152)
Length 1st dorsal base	98.8	.126	58.5	.113	40.4	.116	39.4	(.115)
Height posterior margin D_1	86.6	.111	50.9	.099	29.6	.085	28.8	(.084)
Length free rear tip D_1	49.9	.064	31.1	.060	19.6	(.056)	20.0	(.058)
Height 2d dorsal	33.9	.043	20.0	.039	15.1	(.044)	17.3	(.050)
Length 2d dorsal base	26.2	.034	18.1	.035	11.7	.034	12.6	(.037)
Length free rear tip D_2	52.0	.066	31.2	.060	22.4	.065	21.3	(.062)
Height anal	56.9	.073	32.0	.062	22.9	(.066)	22.9	(.067)
Length anal base	33.4	.043	21.1	.041	17.4	.050	15.5	.045
Length free rear tip anal	46.6	.060	32.5	.063	22.4	.066	20.5	(.060)
Length pelvic	75.9	.097	47.5	.092	31.5	.091	32.3	(.094)
Width pelvic base	31.9	.041	19.6	.038	13.9	.040	13.5	(.039)
Pelvic origin to anal origin	146.2	(.187)	90.9	.176	65.5	(.189)	65.5	(.191)
Pelvic origin to pectoral origin	303.4	.388	205.2	(.398)	123.7	(.356)	118.1	(.344)
Length anterior margin of P_1	189.7	(.243)	105.0	(.203)	73.2	(.211)	71.9	(.210)
Length posterior margin of P_1	52.9	(.067)	31.7	.061	23.0	(.066)	21.4	(.062)
Length distal margin of P_1	150.0	(.192)	85.0	(.165)	42.5	(.122)	48.5	(.141)
Length upper caudal lobe	289.5	(.370)	191.4	(.371)	130.6	(.376)	132.6	(.386)
Length lower caudal lobe	139.0	(.178)	79.0	(.153)	53.4	(.154)	55.4	(.161)
Tip of snout to origin D_1	379.0	(.485)	252.4	.489	169.6	.489	169.3	(.493)
Tip of snout to origin D_2	695.0	(.889)	458.5	.888	304.0	(.876)	299.5	(.873)
Tip of snout to anal origin	681.0	(.871)	451.5	(.875)	302.5	(.872)	287.5	(.838)
Tip of snout to pelvic origin	534.0	(.683)	363.4	(.704)	240.5	(.693)	230.7	(.672)
Tip of snout to pectoral origin	251.0	(.321)	175.6	(.340)	121.0	(.349)	117.5	(.342)
Origin D_1 to origin D_2	333.4	(.426)	210.5	(.408)	139.0	(.400)	139.1	(.405)
Origin D_2 to upper precaudal pit	94.0	(.120)	62.9	(.122)	43.4	(.125)	43.3	(.126)
Origin anal to lower precaudal pit	98.2	(.126)	60.0	(.166)	47.9	(.138)	45.0	(.131)

have broad teeth. When the large assemblage of Indo-Pacific forms is examined, the situation will undoubtedly be found to be even more complex. With respect to other characters, the use of the presence or absence of a mid-dorsal ridge as a generic character would associate forms such as *leucas*, *remotus*, and *velox*, which appear to have little else in common, and separate *azureus* and *nicaraguensis*, which are otherwise quite similar. In addition, the situation regarding intraspecific variation in this character is by no means clear. In the related *Scoliodon terraenovae* a mid-dorsal ridge may be either present or absent

(Springer, 1950), suggesting that a similar situation may be present in some of the species of *Carcharhinus*. It is possible that some of the variation in this feature attributed to differences of preservation is in actuality due to intraspecific variation. Any judgment as to the stability of this character must be held in abeyance until much larger series of specimens have been examined. In the light of the foregoing discussion, it is our opinion that the use of the mid-dorsal ridge to subdivide *Carcharhinus* would produce much confusion and shed little light on relationships. It appears that if the genus is to be subdivided, new characters must be sought, preferably by someone considering the world assemblage of forms.

Carcharhinus malpeloensis appears to be most closely related to the Atlantic species *C. floridanus* (Müller and Henle). It resembles that species most importantly in that the free rear tips of the second dorsal and anal fins are elongate, the first dorsal is low and rounded, and the pectoral is short. It differs chiefly from that species in that the snout is more elongate and less broadly rounded, the first dorsal is lower, and the teeth of the upper jaw are more erect and have narrower cusps.

From *C. floridanus*, the other Atlantic species with elongate free rear corners of the second dorsal and anal, *malpeloensis* differs in many respects, being similar only in snout shape.

C. malpeloensis does not appear to be especially closely related to any of its eastern Pacific congeners. It approaches *C. porosus* in its short pectoral fin and relatively long snout, but differs widely from that species in dorsal fin shape, tooth shape, and the level of insertion of the second dorsal and anal fins. *C. malpeloensis* is separated from the other eastern Pacific species of *Carcharhinus* in the following key.

KEY TO THE EASTERN PACIFIC SHARKS OF THE GENUS *CARCHARHINUS*

1 Pectoral and first dorsal fins extremely long, tips broadly rounded (Figure 3). Preoral length 4.0 or more in pectoral length, 2.8 in height of first dorsal. Free rear corner of anal very long, reaching lower precaudal pit. Pectoral and first dorsal either white-tipped or mottled with gray______*C. longimanus* (p. 148)

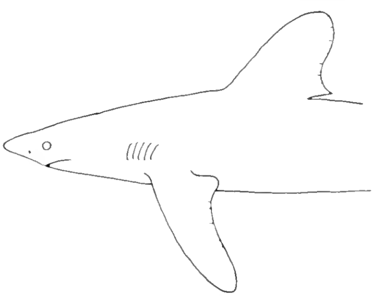

FIGURE 3

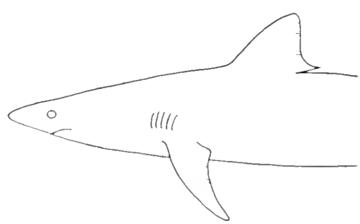

FIGURE 4

Pectoral and first dorsal fins not notably elongate, tips not broadly rounded (Figure 4). Preoral length 2.8 or less in pectoral length, 2.4 or less in height of first dorsal. Free rear corner of anal short to elongate, its tip never reaching beyond a point one eye diameter in advance of lower precaudal pit. Fins plain or black-tipped, except in *C. platyrhynchus*, in which the fin tips and trailing edges are white______________________________________ 2

2 Snout extremely long and slender, preoral length notably greater than mouth width. Nostrils large, horizontally placed and close together; length of nostril 1.4 in internarial distance (Figure 5). Eye 5.8 in preoral length
C. velox (p. 148)

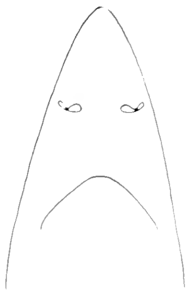

FIGURE 5

FIGURE 6

Snout not extremely long and slender, preoral length slightly greater to much less than width of mouth. Nostrils oblique, normal in size and position, not especially close together; length of nostrils 2.4 or more in internarial distance (Figure 6). Eye 4.8 or less in preoral length 3

3 Origin of second dorsal opposite or behind a vertical from the middle of the anal base (Figure 7). Anterior margin of nostril expanded at inner end into a pointed lobe (Figure 9) *C. porosus* (p. 149)

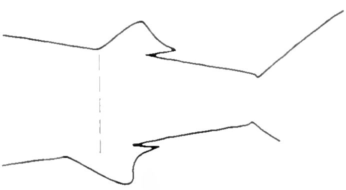

FIGURE 7

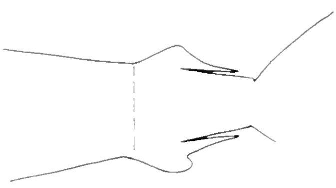

FIGURE 8

FIGURE 9

FIGURE 10

Origin of second dorsal over, slightly behind, or in advance of anal origin, never over middle of anal base (Figure 8). Anterior margin of nostril with at most a triangular lobe (Figure 10) ______ 4

4 Tips and trailing edges of all fins edged with white (white margin may be quite narrow on second dorsal fin). Eye large, fleshy orbit greater than height of fifth gill slit and 9.5 in distance between tip of snout and a line between pectoral origins______ *C. platyrhynchus* (p. 150)

Tips and trailing edges of all fins either black or plain colored. Eye smaller, fleshy orbit equal to or less than height of fifth gill slit and 10 to 14 in distance between tip of snout and a line between pectoral origins______ 5

5 [illegible] length 1.[illegible] [illegible] width. Internarial distance [illegible] (Figure 11). Origin of second dorsal [illegible] the base of second dorsal (Figure 12) [illegible] *C. [illegible]us* (p. 151)

FIGURE 11

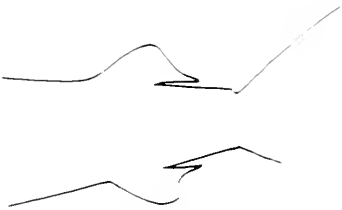

FIGURE 12

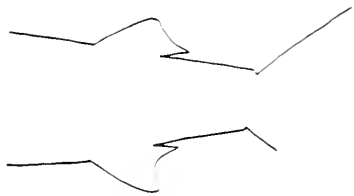

FIGURE 13

[illegible] length equal to or only [illegible] Internarial distance less than preoral length. Origin [illegible] slightly behind that of anal, not [illegible] (Figure 13) [illegible] 6

6 P[illegible] first dorsal. First [illegible] free rear corner less than 3.0 in height (Figure 14). Free [illegible] slender, distance between [illegible] upper precaudal pit about equal [illegible] P[illegible] length of pelvic more than 5.0 [illegible] insertion of first dorsal fin.
C. [illegible]ampeloensis (p. 152)

FIGURE 14

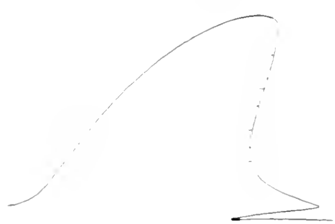

FIGURE 15

P[illegible] posterior corner of the first dorsal [illegible] First dorsal [illegible] free rear corner more than 3.0 in height (Figure 15). Free rear corners of second dorsal and anal not long and slender, distance between end of free rear corner of second dorsal and upper precaudal pit much greater than diameter of fleshy orbit. Pelvic fins longer, length of pelvic less than 4.5 in distance between tip of snout and insertion of first dorsal [illegible] 7

7 No dermal ridge [illegible] Mo[illegible] of upper [illegible] with [illegible] F[illegible] elongate [illegible] internarial [illegible] first dorsal [illegible] 8

FIGURE 16

FIGURE 17

A[illegible] 9

8 L[illegible] 1[illegible] upper [illegible]

L[illegible] 1.0[illegible] 3.4—4.1 [illegible] T[illegible]

9 First dorsal [illegible] of posterior [illegible] greater [illegible] 2.1—2.7 [illegible] of subterminal [illegible]

FIGURE 18

FIGURE 19

First dorsal lower, its apex slightly rounded, posterior margin not vertical, but slightly concave (Figure 19). Length of base of first dorsal 0.9—1.1 in height of posterior margin. Height of posterior margin of first dorsal less than distance between tip of snout and anterior margin of eye, 2.8—3.1 in head length. Length of nostril 3.2—3.8 in preoral length. Subterminal notch of caudal 3.5—4.8 in lower caudal lobe ________________ *C. [illegible]iella* (p. 157)

Carcharhinus longimanus (Poey)

Squalus longimanus Poey, 1861, p. 338 (Cuba).

Back with a dermal ridge between the dorsal fins. Snout short and bluntly rounded, preoral length equal to $\frac{3}{4}$ of mouth width. Eye small, fleshy orbit 5.0 in preoral length and 14.8 in distance from tip of snout to a line between pectoral origins. First dorsal extremely high and broadly rounded, its vertical height 1.2 in head length. Second dorsal and anal large, anal larger than second dorsal. Second dorsal and anal with elongate free rear tips, that of anal reaching lower precaudal pit. Origin of second dorsal in advance of that of anal by a distance equal to $\frac{1}{3}$ the length of base of second dorsal. Pectoral very long and broad, its tip rounded, reaching well beyond posterior end of first dorsal base. Teeth of upper jaw broadly triangular and coarsely serrate. Teeth of lower jaw symmetrical, with elongate, erect cusps set on wide bases. Cusps of teeth of lower jaw finely serrate, bases smooth. Dermal denticles closely spaced but little overlapping. Each denticle broader than long, with 5 to 7 spine-bearing ridges. Back brown to bluish gray. Belly off white to dirty yellow. Fins lighter than body; pectorals, pelvics and first dorsal often white-tipped or mottled with gray. Second dorsal and anal may be black-tipped.

This species is most likely to be confused with *C. platyrhynchus*, which also has a short snout and white-tipped fins. *C. longimanus* differs markedly from *platyrhynchus* in its long, rounded first dorsal and pectoral, long free rear tips on the second dorsal and anal, and small eye size. *C. longimanus* is similar to *C. azureus* in that the snout is short and blunt and the origin of the second dorsal is in advance of that of the anal, but differs greatly from that species in fin length and shape as well as in a number of other characters. Early embryos of almost any species of *Carcharhinus* will resemble *C. longimanus* in having the first dorsal and pectoral rounded, since this appears to be an embryonic feature of *Carcharhinus*. The fins of embryos of *longimanus* are quite large, so that little confusion should result. This species is well figured by Bigelow and Schroeder (1948, p. 355).

Range: Pelagic in warm seas throughout the world. Only once recorded from the eastern Pacific (Hubbs, 1951).

Material examined: Off Central America (9° 56.0′ N., 109° 59.0′ W.), UCLA55-304 1(1,380 mm.).

Carcharhinus velox Gilbert

Carcharhinus velox Gilbert, in Jordan and Everman, 1898, p. 2,747 (Panama).

No dermal ridge on back between dorsal fins. Snout pointed, extremely elongate, mouth width 1.5 in preoral length. Nostrils extremely large, horizontal in position and close together; nostril length 1.4 in internarial distance. Eye moderate, 5.8 in preoral length and 14 in distance between tip of snout and a line between pectoral origins. Gill openings large, first gill slit almost twice as large as fleshy orbit. First dorsal high and falcate, vertical height slightly less than 2 in head. Second dorsal and anal small, anal slightly the larger. Free rear tips of second dorsal and anal short. Origin of anal slightly in advance of origin of second dorsal. Pectoral pointed but not falcate, proximal portion very broad, width of pectoral base 1.7 in length of posterior margin. Pectoral relatively long, extending beyond posterior end of first dorsal base. Teeth of upper jaw narrowly triangular, with elongate, finely serrate cusps. Teeth of lower jaw symmetrical, with elongate serrate cusps set on wide bases. Dermal denticles overlapping, little broader than long, edges rounded. Each denticle with 5 to 7 ridges. Back gray-brown, belly ivory. Trailing edges of pectoral and pelvic fins narrowly edged with white, other fins gray.

The extremely long, slender snout and large, horizontally placed nostrils immediately separate this species from all other species of *Carcharhinus*. No other form shares this peculiar combination of characters. This species has been figured by Gilbert and Starks (1904), Beebe and Tee-Van (1941), and Roedel (1950).

Range: Bahia Santa Maria, Baja California, and Punta Santo Domingo, Golfo de California, to Bahia de Panama.

Material Examined: Mexico, Baja California (23° 01′ 30″ N., 109° 26′ W.), UCLA49-391 1 (1,000 + mm.); Bahia Santa Maria, UCLA52-247, one set of jaws from a 54-in. specimen.

Carcharhinus porosus (Ranzani)

Carcharias porosus Ranzani, 1840, p. 8, pl. 2 (Brazil).
Carcharhinus cerdale Gilbert, in Jordan and Everman, 1898, p. 2,746 (Panama).
Carcharhinus lamiella (not of Jordan and Gilbert), Kumada and Hiyama, 1937, p. 16, pl. 48.

No dermal ridge between dorsal fins. Snout elongate and pointed, preoral length slightly less than mouth width. Width of snout at outer margins of nostrils slightly less than or equal to preoral length. Anterior margin of nostril expanded at inner end into a pointed lobe. Eye small, fleshy orbit 4.8 in preoral length, 12.5 in distance between tip of snout and a line between pectoral origins. Gill openings moderate, becoming relatively larger with increasing size, diameter of fleshy orbit 1.2-2.0 in first gill slit. First dorsal low and wide, only slightly falcate (posterior margin becoming more concave with increasing size; compare illustrations in Gilbert and Starks (1904) and Bigelow and Schroeder (1948)); height more than two in head. Second dorsal and anal small, anal slightly the larger. Free rear tips of second dorsal and anal short. Origin of second dorsal over middle of anal base. Pectoral short and wide, ending before a vertical from posterior end of first dorsal base. Distal margin of pectoral almost straight. Lower precaudal pit well developed, crescent-shaped. Teeth of upper jaw finely serrate. Cusps of upper teeth elongate and narrowly triangular, the medial margin little concave, evenly and steeply sloping. Median teeth of lower jaw symmetrical, becoming progressively more asymmetrical laterally until the last few teeth resemble the lateral teeth of the upper jaw. Dermal denticles widely spaced, with skin exposed between them. Denticles only a little broader than long, each with 3 to 5 tooth-bearing ridges, central tooth longest. Back blue-gray, belly and lower sides pale, the line of demarcation between the two colors rather sharp. Fins with a slight brownish-red cast. Trailing edges of pectorals and pelvics light. Caudal dark margined.

The combination of characters given in the key and the preceding diagnosis serves to distinguish this species from its eastern Pacific congeners. We have been unable to find any characters which might serve to separate the nominal species *C. cerdale* from *C. porosus*. Our eastern Pacific material agrees well with the description and figures of Atlantic material given by Bigelow and Schroeder (1948, p. 394-399), with the exception that the medial margins of the upper jaw teeth appear to be more concave than indicated in their Figure 74A.

Range: Tropical western Atlantic; Mexico, Baja California, Golfo de California, San Felipe (new record) to Payta, Peru; Galapagos Islands.

Material Examined: Mexico, Baja California, Golfo de California, San Felipe, UCLA52-122 1(905 mm.); Panama, mouth of Rio Anton, UCLA54-325 1(375 mm.); between Panama City and Punta Gorda, UCLA53-275 2(385 mm., 480 mm.); Fish Collection, Scripps Institution of Oceanography: Mexico, Baja California, Golfo de California, San Felipe, S1057-205 1(937 mm.).

Carcharhinus platyrhynchus (Gilbert)

Eulamia (Platypodon) platyrhynchus Gilbert, 1892, p. 543 (Islas Revillagigedo).

Back with a dermal ridge between the dorsal fins. Snout bluntly rounded, width of mouth 1.2 in preoral length. Eye large, 3.5 in preoral length and 10.5 in distance between tip of snout and a line between pectoral origins. Gill slits moderate, length of first gill slit about equal to diameter of fleshy orbit. Length of fifth gill slit much less than that of fleshy orbit. First dorsal triangular, its apex sharp, its height 2.2 in head length. Second dorsal and anal small, anal slightly the larger. Origin of second dorsal opposite anal origin. Free rear tips of second dorsal and anal short. Pectoral falcate, reaching beyond posterior end of first dorsal base. Teeth of upper jaw broadly triangular, strongly serrate. Teeth of lower jaw symmetrical, with elongate serrate cusps set on wide bases. Dermal denticles slightly overlapping, about as wide as long. Each denticle with three ridges which bear teeth and two lateral ridges which do not. Back slate gray, belly white. Tips and trailing edges of pectorals and first dorsal white. Pelvics, anal, and caudal white-margined.

The white-tipped fins immediately distinguish this species from all the other eastern Pacific species of *Carcharhinus* except *C. longimanus*. *C. platyrhynchus* is distinguished from *longimanus* in the discussion of that species. In general body shape and fin configuration, *platyrhynchus* is quite similar to the *galapagensis-lamiella* complex, being distinguished from those species by the larger eye and white fin tips. Beebe and Tee-Van (1941) attempted to separate *platyrhynchus* and *lamiella* on the basis of relative coarseness of serration of the teeth. We have been unable to confirm the differences mentioned by Beebe and Tee-Van. We have found differences between teeth from a single individual to be as great as any differences between the teeth of individuals of *platyrhynchus* and *lamiella*. This finding casts considerable doubt on Beebe and Tee-Van's listing of Jordan and Gilbert's (1883a) Mazatlan record of *Carcharias* sp. incog. in the synonymy of the insular species *platyrhynchus*.

Gilbert's original description, which was based on material from Clarion and Socorro Islands and Magdalena Bay, Baja California, applies to at least two and probably three species. He states " . . . the fins conspicuously margined with white in the largest specimen obtained, without margins in the others." Gilbert's non white-tipped specimens from the Revillagigedo Islands are probably referable to *C. galapagensis*, which is the most common shark in that area. The Magdalena Bay specimen reported by Gilbert is in all probability *C. lamiella*, rather than *C. galapagensis* as listed by Beebe and Tee-Van (see discussion of the relationship between these species in our treatment of *galapagensis*). Although the name *platyrhynchus* antedates *galapagensis* and could be applied to the gray-finned *Carcharhinus* of the offshore islands, authors subsequent to Gilbert have been uniform in applying the name *platyrhynchus* to the eastern Pacific white-tip. In the interests of stability and uniformity, we follow this implied type designation of earlier authors (Snodgrass and Heller, 1905; and others) and take this opportunity to designate Gilbert's white-tipped Socorro Island specimen, U. S. N.M. 46847, as the lectotype of *C. platyrhynchus*.

Range: Oceanic islands of the eastern Pacific; Islas Revillagigedo, Clipperton Island, Isla Cocos, Galapagos Islands.

Material Examined: Mexico, Islas Revillagigedo, Isla Socorro, UCLA 53-51 1(1,050 mm.); Isla San Benedicto, UCLA55-121 2(770 mm., 860 mm.); Isla Cocos, UCLA55-306 1(1,058 mm.).

Carcharhinus azureus (Gilbert and Starks)

Carcharias azureus Gilbert and Starks, 1904, p. 11, pl. 2 (Panama).

Back with a dermal ridge between the dorsal fins. Snout short and bluntly rounded, preoral length about 1.8 in mouth width. Internarial distance greater than preoral length. First dorsal moderately high and triangular, its height 1.5 or more in head length. Second dorsal and anal relatively large, anal the larger. Free rear tips of second dorsal and anal short, ending far in advance of precaudal pits. Origin of second dorsal in advance of origin of anal by a distance equal to $\frac{1}{3}$ the length of second dorsal base. Pectoral moderate, reaching to posterior end of first dorsal base, its tip little rounded. Teeth of upper jaw broadly triangular and coarsely serrate. Teeth of lower jaw symmetrical, with elongate, triangular cusps. Cusps of lower teeth serrate. Back bluish gray, belly white. Caudal and second dorsal black-margined, lower caudal lobe and distal portion of pectoral dark.

Early embryos of this species differ considerably from adults and will probably not fit the key. In a 310-mm. specimen the snout is longer and more pointed, the preoral length being contained 1.3 times in the mouth width. The general configuration of the snout is, however, quite similar to that of the adult. A posterior extension of the color of the upper side onto the lower side, as in *C. limbatus*, is also present in this specimen. As is typical for embryonic *Carcharhinus*, the fins are much shorter than in the adult.

The blunt snout and the position of the second dorsal and anal origins set this species off from all eastern Pacific *Carcharhinus* except *C. longimanus*. It is distinguished from *longimanus* in the discussion of that species.

Except for the presence of a mid-dorsal ridge, *C. azureus* appears to be very similar to the freshwater species *C. nicaraguensis*, which in turn is doubtfully distinct from the Atlantic *C. leucas*. The relationships of these species cannot be clarified until more material becomes available. This species has been figured by Gilbert and Starks (1904).

Range: Southern California to Guayaquil, Ecuador.

Material Examined: Mexico, Baja California, vicinity Bahia Magdalena, UCLA48-1 1 (310 mm.).

Carcharhinus malpeloensis (Fowler)

Eulamia malpeloensis Fowler, 1944, p. 299, Fig. 7-9 (Isla Malpelo, Colombia).

Back with a dermal ridge between the dorsal fins. Snout somewhat elongate and narrowly rounded, preoral length slightly less than mouth width. Width of snout at anterior margins of nostrils slightly less than preoral length. Eye moderate, fleshy orbit 4.5 in preoral length and 10.8 in distance between tip of snout and a line between pectoral origins. Gill openings moderate, fleshy orbit 1.5-2.0 in length of first gill slit. First dorsal low, its apex rounded, vertical height more than 2 in head. Posterior margin of first dorsal slightly convex. Second dorsal and anal small, anal noticeably the larger. Free rear tips of second dorsal and anal long and slender, distance between free rear tip of second dorsal and upper precaudal pit equal to diameter of fleshy orbit. Origin of second dorsal slightly behind that of anal. Pectoral short, ending under posterior third of first dorsal base, its distal margin concave. Teeth of upper jaw serrate and narrowly triangular. Lateral margins of upper jaw teeth notched, inner margins gently convex, but with a slight shoulder where the cusps grade into the base. Teeth of lower jaw symmetrical, with elongate narrow cusps set on wide bases. Bases and cusps of lower teeth smooth. Dermal denticles slightly longer than wide, overlapping. Each denticle with 3-5 ridges, the three median ridges tooth-bearing.

The relationships of this species are discussed at length in the section following our redescription of it.

Range: Vicinity of Isla Clarion, Islas Revillagigedo (18° 25′ N., 114° 50′ W.), to Isla Malpelo, Colombia.

Material Examined: Gulf of Panama, 7° 28.4′ N., 79° 11.4′ W., UCLA55-63 1 (480 mm.); mouth of Rio Anton, UCLA54-325 1 (415 mm.); south of Costa Rica (7° 23.8′ N., 86° 29.6′ W.), UCLA55-307 2 (710 mm., 1,072 mm.); Mexico, vicinity Islas Revillagigedo (18° 25′ N., 114° 50′ W.), UCLA54-265 5 embryos (480 mm.).

Carcharhinus remotus (Duméril)

Carcharias (Prionodon) remotus Duméril, 1865, p. 374 (Antilles).

No dermal ridge between dorsal fins. Snout slightly elongate, narrowly rounded, preoral length almost equal to mouth width. Width of snout at anterior margins of nostrils slightly greater than preoral length. Eye moderate, fleshy orbit 4 in preoral length, 10.5 in distance between tip of snout and a line between pectoral origins. Gill openings small, length of first gill slit less than 1.5 times the diameter of fleshy orbit. First dorsal low, 2.5 in head, its apex narrowly rounded. Posterior margin of first dorsal oblique and weakly concave. Second dorsal and anal small, anal the larger. Free rear tips of second dorsal and anal short. Origin of second dorsal slightly behind origin of anal. Pectoral moderate, slightly falcate, ending at or slightly behind a vertical from posterior end of first dorsal base. Lower precaudal pit triangular, very weakly developed. Teeth of upper jaw symmetrical, developed as elongate serrated cusps set on wide bases. Teeth of lower jaw symmetrical, cusps serrate. Dermal denticles overlapping, almost circular, with 3 (rarely 5) tooth-bearing ridges (when 5 ridges are present the lateral teeth are weakly developed). Back gray, belly and lower sides light. Color of upper back continued on lower side, forming a light band between back and the band-like continuation of the color of the back onto the lower side.

TABLE 2

Carcharhinus remotus: Measurements of Body Parts and Proportions in Length Without Caudal

	1150-224 California, Off Encinitas		1150-200 California, Off Oceanside		California, Off Oceanside	
Sex			♂		♂	
Total length	690.0		760.0		860.0	
Length without caudal	505.0		551.0		620.0	
Trunk width over pectoral origins	70.4	0.139	79.5	0.144	91.4	0.147
Trunk height at pectoral origins	77.5	.154	87.6	.158	92.7	.150
Head length	168.5	.334	182.9	.330	210.6	.340
Head width at angles of mouth	78.1	.155	82.6	.149	97.4	.157
Interorbital width	71.9	.142	79.0	.143	87.9	.142
Head width at outer ends of nostrils	53.3	.106	60.6	.109	68.4	.110
Mouth width	48.3	.096	59.2	.107	65.0	.105
Mouth length	32.0	.063	32.4	.085	42.2	.068
Fleshy orbit diameter	14.0	.028	14.9	.027	15.0	.024
Preoral length	51.0	.101	58.3	.105	61.6	.101
Prenarial length	26.4	.052	27.8	.050	33.9	.055
Nostril length	10.0	.020	12.5	.023	13.1	.021
Internarial distance	39.0	.077	44.2	.080	49.8	.080
Length labial fold	3.9	.007	3.1	.006	5.0	.008
Length 1st gill slit	17.9	.035	20.9	.038	20.6	.042
Length 2d gill slit	19.0	.038	22.4	.040	22.4	.036
Length 3d gill slit	20.5	.041	21.6	.039	22.5	.036
Length 4th gill slit	18.9	.037	18.4	.033	20.5	.033
Length 5th gill slit	15.2	.030	14.7	.026	18.3	.030
Origin P_1 to base first gill slit	32.1	.064	35.7	.061	38.5	.062
Height first dorsal	68.3	(.136)	76.0	(.137)	91.1	(.147)
Length first dorsal base	60.5	(.120)	66.5	(.120)	75.1	(.121)
Height posterior margin D_1	53.8	(.106)	57.9	(.105)	73.6	(.119)
Length free rear tip D_1	24.3	(.048)	26.8	(.048)	26.6	(.043)
Height 2d dorsal	25.6	(.051)	27.2	(.049)	30.6	(.049)
Length 2d dorsal base	25.9	(.051)	25.0	(.045)	30.0	(.048)
Length free rear tip D_2	26.0	(.051)	27.4	(.049)	30.0	(.048)
Height anal	40.0	(.079)	41.9	(.076)	44.7	(.072)
Length anal base	29.0	(.057)	28.9	(.052)	31.3	(.050)
Length free rear tip anal	24.3	(.048)	24.8	(.045)	26.9	(.043)
Length pelvic	55.4	(.080)	54.0	(.097)	64.2	(.104)
Width pelvic base	20.6	(.041)	21.0	(.038)	25.8	(.042)
Pelvic origin to anal origin	83.3	(.173)	84.6	(.153)	112.0	(.181)
Pelvic origin to pectoral origin	187.0	(.370)	217.0	(.392)	229.9	(.371)
Length anterior margin of P_1	113.5	(.225)	121.0	(.218)	140.5	(.226)
Length posterior margin of P_1	37.5	(.074)	40.9	(.074)	44.7	(.072)
Length distal margin of P_1	90.1	(.178)	96.6	(.174)	114.1	(.184)
Length upper lobe caudal	194.3	(.385)	209.9	(.379)	234.1	(.378)
Length lower lobe caudal	81.5	(.161)	87.6	(.158)	104.7	(.169)
Tip of snout to origin D_1	228.5	(.452)	253.6	(.458)	286.5	(.462)
Tip of snout to origin D_2	436.0	(.863)	479.0	(.865)	545.0	(.879)
Tip of snout to anal origin	422.0	(.836)	466.0	(.841)	530.0	(.855)
Tip of snout to pelvic origin	347.0	(.687)	381.0	(.688)	425.0	(.686)
Tip of snout to pectoral origin	162.5	(.322)	179.2	(.324)	198.5	(.320)
Origin D_1 to origin D_2	219.9	(.435)	240.5	(.434)	273.3	(.440)
Origin D_2 to upper precaudal pit	69.8	(.138)	83.0	(.150)	83.6	(.135)
Origin anal to lower precaudal pit	73.5	(.146)	83.0	(.150)	89.3	(.144)

Among the smooth-backed *Carcharhinus remotus* may be most easily confused with *limbatus* and *porosus*. *C. remotus* resembles *limbatus* in tooth shape, but is easily distinguished from that species by a number of characters. In *limbatus* the gill slits are larger, the eye smaller, the free rear tips of the second dorsal and anal longer, the lower precaudal pit crescent-shaped and well developed, and the fins black-tipped. *C. remotus* and *C. porosus* have little in common except that in both species the origin of the second dorsal is behind the origin of the anal. This similarity is quite superficial, since in *remotus* the second dorsal origin is only slightly behind that of the anal, while in *porosus* the second dorsal origin is over the middle of the anal base. In addition, the species differ in the length and shape of the pectoral, shape of the anterior margin of the nostril, and tooth shape.

The western Atlantic species *Carcharhinus remotus* has not heretofore been reported from the Pacific. The present record is based on three specimens from southern California. These specimens were collected in the summer of 1950 by a local fish collector, Mr. George Wernham, who presented them to Dr. Carl L. Hubbs of the Scripps Institution of Oceanography, University of California. They were identified at that time as *C. remotus* by Dr. Hubbs. There may have been a fair sized population of *remotus* in California at that time since Hubbs *(in litt.)* mentions them as being present in ". . . small commercial quantities". Upon learning of the present study, Dr. Hubbs kindly turned over his material to us for further investigation. Although we have had no Atlantic material for direct comparisons, the California specimens have been compared in detail with the excellent description and figures given by Bigelow and Schroeder (1948, p. 400-403). No differences were found in any character. Morphometric measurements taken from these specimens are presented in Table 2.

Range: Western tropical and subtropical Atlantic. Known only from the vicinity of Oceanside, California, in the eastern Pacific. It is almost certain that this species will be found to have a wider range in the eastern Pacific. It is possible that Springer's 1950 Panama record of *C. galapagensis* may apply to *remotus*.

Material Examined: Fish collection, Scripps Institution of Oceanography: California, San Diego Co., North of Oceanside, H50-200 1 (760 mm.); off Encinitas, H50-224 1 (690 mm.); vicinity of Oceanside, no collection number, 1 (860 mm.).

Carcharhinus limbatus (Müller and Henle)

Carcharias (Prionodon) limbatus Müller and Henle, 1841, p. 49, pl. 19 (no locality).

Carcharias aethalorus Jordan and Gilbert, 1883a, p. 104 (Mazatlan, Mexico).

Carcharhinus natator Meek and Hildebrand, 1923, p. 41, pl. 1 (Panama).

No dermal ridge between dorsal fins. Snout somewhat elongate, narrowly rounded, preoral length slightly less than mouth width. Width of snout at outer margins of nostrils less than preoral length. Eye small, fleshy orbit 4.5 in preoral length and 12 in distance between tip of snout and a line between pectoral origins. Gill openings moderate, length of first gill slit at least twice the diameter of fleshy orbit. First dorsal high, height less than 2 in head. Posterior margin of first dorsal concave, giving the fin a hooked, falcate appearance. Second dorsal and anal small, the anal scarcely the larger. Free rear tips of second dorsal and anal moderate, distance between end of free rear tip of anal and lower precaudal pit being equal to eye. Pectoral long and falcate, extending beyond the posterior end of first dorsal base. Lower precaudal pit crescent-shaped, well developed. Teeth of upper jaw symmetrical, developed as elongate serrated cusps set on wide bases. Teeth of lower jaw symmetrical, cusps serrate. Dermal denticles overlapping, diamond shaped, with 5-7 tooth-bearing ridges. Back gray to bronze, belly and lower sides yellowish white with a band of the dark color of the upper back extending rearward along the lower side to about over the origin of the pelvic, enclosing above it a forward extension of the lighter color of the lower side. This color pattern may be very faint to strikingly obvious. Fins prominently black-tipped, more so in young than adults.

Among the smooth-backed members of the genus found in the eastern Pacific, *C. limbatus* appears to be most similar to *C. remotus*. It is separated from *remotus* in the discussion of that species. This species has been figured by Beebe and Tee-Van (1941) and Bigelow and Schroeder (1948).

We have before us the head and tail of an eight-foot specimen taken at Clipperton Island (UCLA56-239). The tooth shape, snout length, and eye size agree well with *C. limbatus* but the snout is somewhat more rounded and broader, the width of the head at the outer margin of the nostrils being slightly greater than the preoral length. In life the fins were not black-tipped and the characteristic band-like continuation of the color of the back onto the lower sides was not present. Seven small embryos (350 mm.) taken from this adult also lack the black fin tips. The fins are all short, as is to be expected, but the posterior margin of the first dorsal is quite concave, agreeing well with *C. limbatus*. The band-like color continuation is very weakly developed. The snout is less broad and considerably less rounded than in adults. We are unable to determine with certainty whether the embryos possess a ridge between the dorsal fins. The characters shown by the embryos are probably not reliable, since *C. limbatus* is born at a considerably greater size (three embryos from the Galapagos Islands (UCLA53-152) still lack teeth at 620 mm.). Although subsequent specimens may prove that there is still another species of *Carcharhinus* in the eastern Pacific, we are provisionally referring this material to *C. limbatus*.

Range: Tropical Atlantic; west coast of Baja California and Bahia Concepcion, Golfo de California, to Punta Coles, southern Peru. Galapagos Islands (new record).

Material Examined: Mexico, Golfo de California, Sinaloa, UCLA 51-48 1(890 mm.); Baja California, Bahia Coyote, UCLA53-100 (jaws from an 870 mm. specimen); Panama, UCLA53-267 1(594 mm.); Clipperton Island (10° 17′ N., 109° 13′ W.), UCLA56-239 8(7 embryos 325 mm. to 330 mm. removed from an 8-ft. specimen of which the head and tail sections were retained); Galapagos Islands, Bartholomew Island, UCLA53-157 3(595 mm.-620 mm.).

Carcharhinus galapagensis (Snodgrass and Heller)

Carcharias galapagensis Snodgrass and Heller, 1905, p. 343 (Galapagos Islands, Tower Island).
Eulamia lamiella (?) Jordan and Bollman, 1890, p. 179 (Galapagos Islands).

Back with a dermal ridge between the dorsal fins. Snout bluntly rounded, rather short, preoral length not equal to mouth width. Eye moderate, fleshy orbit 4 in preoral length, 11 in distance from tip of snout to a line between pectoral origins. Gill slits moderate, length of first gill slit slightly less than fleshy orbit. First dorsal triangular, its apex angular and its posterior margin vertical, not concave; vertical height slightly less than 2 in head length. Second dorsal and anal small, anal the larger. Origin of second dorsal slightly in advance of anal origin. Free rear tips of second dorsal and anal short. Pectoral falcate, its tip reaching beyond posterior end of first dorsal base. Teeth of the upper jaw broadly triangular, strongly serrate. Teeth of lower jaw symmetrical, with elongate serrated cusps set on wide bases. Dermal denticles about as wide as long, slightly overlapping. Each denticle with 5-7 ridges, the outer two weaker and not ending in a spine. Color of back slate gray, belly cream, often mottled with gray. Tips and trailing edges of pectoral and first dorsal darker.

The separation of this species from *C. lamiella* is unsatisfactory. The distinguishing features which we have been able to find are those used in the key. The difference noted in the shape of the first dorsal fin is difficult to describe, but appears to be real. The difference in preoral length also seems to be valid. One of the difficulties is insufficient material; while we have 20 specimens of *C. galapagenis*, we have been able to examine only five examples of *C. lamiella*. All of our *lamiella* are from the mainland, all the *galapagensis* are from the oceanic islands. This is in accordance with reports of previous authors (Beebe and Tee-Van, 1941, p. 111). The distribution of *galapagensis* is paralled by that of *platyrhynchus*, which is also known only from the oceanic islands of the eastern tropical Pacific. It is possible that this segregation of material by locality has introduced some bias into our examination. At the present, our conclusion must be that while we are able to distinguish our mainland material from specimens from the offshore islands, an examination of additional material from continental localities might show the differences to be invalid.

Range: Islas Revillagigedo to Galapagos Islands, Isla Cocos, Clipperton Island (new record).

Material examined: Mexico, Islas Revillagigedo, Isla Clarion, UCLA-54-242 2(825 mm., 840 mm.), UCLA55-130 1(865 mm.), UCLA55-135 1(1,000 mm.), Isla Socorro, UCLA55-155 2(785 mm., 825 mm.), Isla San Benedicto, UCLA53-46 1(900 mm.); Clipperton Island (10° 17′ N., 109° 13′ W.), UCLA56-236 10(745 mm., 979 mm.); Galapagos Islands, Pinta Island, UCLA53-9, (jaws from an 11-ft. specimen). Fish Collection, Chicago Natural History Museum: Isla Cocos, CNHM. 17519, one specimen; Galapagos Islands, Albemarle Island, CNHM. 17520, one specimen.

Carcharhinus lamiella (Jordan and Gilbert)

Eulamia lamia (not of Risso) Jordan and Gilbert, 1882, p. 32 (San Diego).
Carcharias lamiella Jordan and Gilbert, 1883a, p. 110 (San Diego and Lower California).

Back with a dermal ridge between the dorsal fins. Snout bluntly rounded, not notably short; width of mouth usually equal to preoral length. Eye moderate, fleshy orbit 4.2 in preoral length and 11 or more in distance from tip of snout to a line between the pectoral origins. Gill slits moderate, length of first gill slit slightly greater than fleshy orbit. First dorsal not very high, a little less than 2 in head. Apex of first dorsal gently rounded, posterior margin of the fin slightly concave. Second dorsal and anal small, anal the larger. Origin of second dorsal slightly in advance of anal origin. Free rear tips of second dorsal and anal short. Pectoral falcate, its tip reaching beyond posterior end of first dorsal base. Teeth of upper jaw broadly triangular, strongly serrate. Teeth of lower jaw symmetrical, with elongate serrated cusps set on wide bases. Dermal denticles about as wide as long, slightly overlapping. Each denticle with five ridges, the middle three well developed and spine bearing. Color of back slate gray, belly cream. The color of the upper back is continued on the lower side, forming a light band between the back and the band-like continuation of the color of the back onto the lower side. Tip of pectoral dark. Apex and trailing edge of first dorsal somewhat darker than the rest of fin.

C. lamiella is distinguished from the other eastern Pacific ridge-backed *Carcharhinus* except *galapagensis* and *malpeloensis* in having the fins plain and the origin of the second dorsal opposite that of the anal. From *malpeloensis* it differs in the longer pectoral and shorter free rear tips of the second dorsal and anal. *C. lamiella* is separated from *C. galapagensis* in the discussion of that species.

This species has been figured by Roedel and Ripley (1950).

Range: San Diego, California to Mazatlan, Mexico.

Material examined: Mexico, Baja California, vicinity Bahia de Sabastian Vizcaino, UCLA49-393 1(922 mm.); Bahia San Roque, UCLA49-399 1(704 mm.); Punta Abreojos, UCLA49-400 1(892 mm.); Bahia Santa Maria, UCLA51-264 2(1,000 mm., 1,080 mm.).

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AMPHIPOD CRUSTACEANS AS FOULING ORGANISMS IN LOS ANGELES-LONG BEACH HARBORS, WITH REFERENCE TO THE INFLUENCE OF SEAWATER TURBIDITY[1,2]

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A survey of fouling and wood-boring animals in Los Angeles-Long Beach Harbors (LA-LBH) in 1950 showed that amphipods comprised one of the most abundant orders of fouling organisms in turbid water. Previous research on settling faunas in harbors has concentrated on barnacles, mussels, tunicates, and other organisms (Woods Hole Oceanog. Inst., 1952), while tubicolous amphipod foulers have received little attention. This may be due to the fact that Los Angeles-Long Beach Harbors, which have not been previously studied, offer an unusually favorable environment for amphipods. These harbors contain sea water with a stable, normal salinity, warm temperatures, and a high turbidity, caused partly by coarse organic detritus usable as food. These factors in combination may favor the detritus-feeding amphipods and polychaetes to a greater degree than the filter-feeding barnacles, mussels, and tunicates.

Much of the flocculent detritus in the harbors results from domestic and industrial pollution, so that the luxuriant growths of the mat-forming organisms discussed herein are biological indicators of these conditions, when they are optimal and below toxic levels. Thus, these organisms may provide a convenient and rather accurate method for measuring the various biological implications of mans' activities in the harbor area.

The investigation was carried out with the cooperation of the Southern California Marine Borer Council (SCMBC), which conducted the 1950 survey, the use of facilities at the Allan Hancock Foundation, and the cooperation of the California Department of Fish and Game. The writer is indebted to the following persons for help in collecting materials and for the identification of animals other than amphipods: Mr. Carroll Wakeman, Testing Engineer, Los Angeles Harbor Department; Dr. Donald J. Reish, Dr. John L. Mohr, and Mr. Charles Horvath of the University of Southern California; Dr. Robert J. Menzies, now of Lamont Geological Observatory, Columbia University; and Mr. Harold Schiller, consulting chemist.

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[2] This work is a direct outgrowth of pollution studies and surveys of harbor faunas supported by the California Department of Fish and Game. It was a basic research problem originated through but carried on lateral to some of those programs. See Calif. D.P.H. (1952, Appendix A) and the introductory remarks of Reish and Winter (1954, p. 105).

METHOD OF STUDY

During the survey made by the SCMBC, a series of wooden test blocks was installed in the waters of Los Angeles-Long Beach Harbors at 15 localities and reclaimed and replaced each four weeks for the period March 31, 1950, to March 3, 1951. The blocks, of Douglas Fir, measured 6 x 2 x 2 inches. They were suspended subtidally on Manila hemp, weighted with cement blocks, and attached to cross braces between pilings and under wharves. The blocks and their inhabitants were preserved in quart jars of 4 percent formalin at the time of removal from the water. Inspection of the amphipods in the debris scraped from the blocks led the writer to conduct a resurvey at several of the stations during the late spring and early summer of 1951.

The SCMBC survey found that a peak of amphipod fouling occurred in the late spring. This coincided with findings at La Jolla in 1933 (Coe and Allen, 1937).

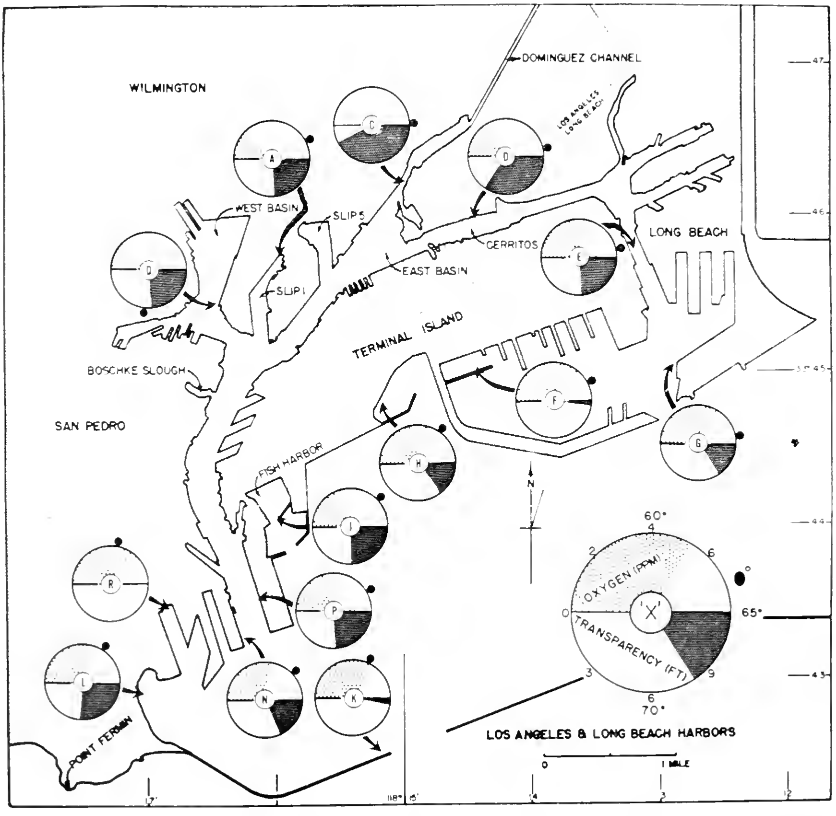

FIGURE 1. Sampling stations occupied in Los Angeles-Long Beach Harbors for the 16-week resurvey period ending August 17, 1951. Each circle represents the average dissolved oxygen (top shading, p.p.m.), turbidity, measured inversely as transparency (bottom, unshaded, feet), and temperature (the peripheral dot, degrees F.) according to the chart legend, for the period March, 1950, to March, 1951. *Data courtesy of SCMBC.*

New installations of test blocks at 14 localities (excluding Stations B and M of SCMBC and adding Station R; Figure 1) included the establishment of a series of four blocks at each station and recovery of one of the four blocks each four weeks, so that the final block was exposed for 16 weeks. The results of the 16-week block exposures form the basis of the present report.

PHYSICAL AND CHEMICAL CONDITIONS

Data concerning water temperature and dissolved oxygen were collected at each station each four weeks (presented by ranges and means in Table 1). Transparency readings using a 30-cm., white Secchi disk were taken during three months of the year. Additional transparency data may be obtained in Calif. D.P.H. (1952). The salinity (measured as chlorinity) in the harbors during the sampling year was relatively uniform at all of the stations, ranging from about 18.2 to 19.4 p.p.t., and was assumed to be unimportant as a variable in the study.

TABLE 1

Physical-Chemical Characteristics at 14 Stations in Los Angeles-Long Beach Harbors, Based on One Reading per Four Weeks at Each Station for Each Variable During the Period March, 1950, to March, 1951. SCMBC Data Except for Station R.

Station	Depth (feet)	Temperature Degrees F.		Dissolved Oxygen (p.p.m.)		Transparency (average of 3 readings feet)
		Yearly range	Yearly average	Yearly range	Yearly average	
A	Surf.	70.0-58.4	63.5	3.5-0.2	2.0	6.33
	20	66.0-56.8	6[illegible].5	3.0-0.0	1.1	
C	Surf.	70.9-58.2	64.9	0.1-0.0	0.0	2.08
D	Surf.	71.5-58.2	64.5	4.4-0.0	2.1	3.75
	20	67.8-56.6	62.6	5.2-0.8	2.9	
E	Surf.	73.2-58.6	64.3	6.7-0.9	4.3	6.25
	20	66.6-55.3	62.2	6.4-1.9	4.4	
F	Surf.	70.6-55.4	63.6	7.3-2.5	5.6	11.67
	20	66.7-55.3	61.1	8.1-2.7	5.7	
G	Surf.	72.0-55.0	64.4	7.2-1.7	5.1	8.00
	10	69.0-56.4	62.3	7.2-2.6	5.4	
H	Surf.	68.0-54.5	62.1	9.3-0.0	4.6	8.00
	20	64.5-54.0	59.7	7.9-0.0	3.9	
J	Surf.	69.7-54.9	62.6	7.5-0.0	3.5	6.00
	10	66.5-54.9	61.4	6.3-0.0	3.0	
K	Surf.	68.9-54.3	61.2	7.5-2.4	5.5	11.50
	40	65.0-54.0	60.4	7.3-2.5	5.5	
L	Surf.	67.7-54.0	61.8	7.7-2.4	4.9	5.50
	10	66.5-54.0	60.6	7.4-2.8	5.1	
N	Surf.	68.3-56.6	62.4	7.5-1.2	4.3	7.33
	20	65.8-55.4	60.9	8.1-1.6	4.4	
P	Surf.	70.8-56.8	63.3	5.2-0.9	3.6	6.50
	10	69.2-55.4	60.9	6.7-0.8	3.9	
Q	Surf.	79.0-63.8	70.7	3.6-0.0	2.0	6.33
	15	71.0-58.6	64.5	3.9-0.1	2.4	
R*	Surf.	66.2-55.4	60.2	6.4-4.7	5.8	12.0

* Ten trials, May, 1951, to March, 1952. Transparency, one trial only.

Seawater data collected during the resurvey of 1951 corresponded favorably with the SCMBC data and are not included herein. It is considered that population density and quality are dependent on average conditions and ranges, rather than on conditions measurable at a single instant (Woods Hole Oceanog. Inst., 1952, p. 48). Therefore, the more comprehensive data of the SCMBC are used to typify the environment at each station.

TYPES OF ENVIRONMENT

Harbor regions show a diversity of marine environment which depends on the variability of the micro-watermass and the substratum, both of which are influenced by the activities of mankind. Los Angeles-Long Beach Harbors, orginally a slough, have been dredged and supplied with thousands of pilings, providing a greatly increased surface area for the attachment of organisms. The shallow and ponded waters of the harbors receive influxes of pollutants and heated water (Calif. D.P.H., 1952). These influence the temperature, dissolved oxygen, and turbidity of the water, probably resulting in wider ranges of variability than would normally be found in arid-type estuaries. In a sense, the physical and chemical environment is harsh and tends to limit the fauna to species which are cosmopolitan and have wide environmental tolerances.

The several stations occupied in the resurvey are listed in Table 2 and the favorability of the environment for each variable is graded on a scale of 1 to 3. Condition 1 is unfavorable for each variable, in-

TABLE 2

Favorability of the Environment at Stations in Los Angeles-Long Beach Harbors.
1 = Unfavorable, 2 = Intermediate, 3 = Favorable. See Below for Ranges of Conditions.

Station	Temperature	Dissolved oxygen	Turbidity	Test block fauna	
				Rich*	Predominant
A	2	1	2	No	Foulers
C	1	1	1	No	No fauna
D	1	1	1	Yes	Foulers
E	1	3	2	No	Foulers
F	2	3	3	Yes	Borers
G	1	3	3	No	Mixed
H	2	3	3?	Yes	Foulers
J	2	2	2	Yes	Foulers
K	3	3	3	Swift current†	
L	3	3	2	Yes	Foulers
N	2	3	3	Yes	Foulers
P	2	2	2	Yes	Foulers
Q	1	1	2	No	Foulers
R	3	3	3	No	Borers

* A rich fauna is classed arbitrarily as one with more than 5,000 organisms on each four-month block. See Table 3 for the numbers of organisms on each block.
† The fauna at this station is not reported upon. The sparsity of organisms was due in part to the swift current near the breakwater entrance.

Grade of Conditions by Ranges

	1	2	3
Temperature, degrees F.	64+	62-64	62−
Dissolved oxygen, p.p.m.	0-2.5	2.5-4.0	4.0+
Turbidity, feet (inverse of transparency)	0-5	5-7	7+

dicating high temperature, low dissolved oxygen, and high turbidity. Condition 2 is intermediate. Condition 3, theoretically a favorable environment, indicates low temperature, high dissolved oxygen, and low turbidity. It will be shown later that high turbidity (condition 1 "unfavorable") is not necessarily a limiting condition, but often is correlated with dense amphipod fouler populations.

THE AMPHIPOD FOULING FAUNA

Amphipods were the most abundant early settlers on fresh surfaces (Table 3). The fauna was composed of seven major species: *Corophium acherusicum* Costa, *C. insidiosum* Crawford, *Jassa falcata* (Montagu),

TABLE 3

Fouling and Boring Organisms in Los Angeles-Long Beach Harbors, by Station, on 16-Week Blocks, Collected August 17, 1951. Based on Total Counts of Organisms.

Station	Foulers			Borers		
	Amphipods	Polychaetes	Others	*Limnoria*	*Chelura*	*Teredo*
A	26	885	57	2	0	0
C	0	0	0	0	0	0
D	4,318	506	349	1	0	2
F	1,505	6	57	9,211	1,853	22
G	1,738	50	60	737	0	362
H	22,298	0	47	5	0	0
J	7,162	563	14	0	0	0
N	3,600	1,200+	7	608	10	0
P	13,131	813	112	12	0	5
Q	1,711	2,109	11	9	0	0
L*	11,019	1,151	303	30	0	22
R†	50	12	12	2,926	33	85
E‡	3,371	171	104	89	0	14

* 16 weeks, collected May 12, 1951.
† 16 weeks, collected December 21, 1951.
‡ 8 weeks, collected June 22, 1951.

TABLE 4

Major Species of Fouling Amphipods in Los Angeles-Long Beach Harbors, by Station, on 16-Week Blocks, Collected August 17, 1951. Based on Total Counts of Organisms.

Station	*Corophium acherusicum*	*Jassa falcata*	*Podocerus brasiliensis*	*Corophium insidiosum*	*Ericthonius brasiliensis*	*Corophium baconi*	*Stenothoe valida*
A	26	0	0	0	0	0	0
C	0	0	0	0	0	0	0
D	3,272	0	111	47	575	0	6
F	460	388	406	14	69	0	0
G	278	1,078	51	6	137	117	9
H	13,177	7,168	39	42	3	1,867	2
J	6,522	78	529	0	13	6	2
N	3,205	17	290	16	1	0	71
P	8,697	0	3,997	432	0	0	4
Q	1,701	0	0	10	0	0	0
L*	3,301	7,596	7	0	3	13	70
R†	17	0	0	0	0	0	12
E‡	1,257	1,421	118	92	355	0	49

* 16 weeks, collected May 12, 1951.
† 16 weeks, collected December 21, 1951.
‡ 8 weeks, collected June 22, 1951.

Podocerus brasiliensis (Dana), *Ericthonius brasiliensis* (Dana), *Stenothoe valida* Dana, all cosmopolitan species (Barnard, 1953), and *Corophium baconi* Shoemaker, a pan-western American species. The abundance and distribution of these amphipods are listed in Table 4.

Except for *Stenothoe valida*, all of the species build sticky parchment tubes to which silt grains and detritus particles adhere. The tubes are attached to solid surfaces above the mud line and accumulate over periods of time into multilayered mats more than an inch thick (Figure 2) and provide shelter for the amphipods. Unlike other tubicolous animals, such as *Polydora*, the amphipods are not obligatorily sessile, but move in and out of the tubes in search of food and to mate. Migration rates are high among the tubicolous amphipods, as evidenced by their early abundance on fresh blocks. It is probable that migration is an incidental result of the necessity to swim while mating. After mating, the animals seek the nearest surface, which may not be the one from which they originated. Passive migration has already been suggested for the wood borer *Chelura terebrans* (Barnard, 1955b).

Stenothoe valida, a non-tubicolous amphipod, lives and feeds among hydroids, especially *Tubularia crocea* (Agassiz), as do two species of *Caprella*, occasional inhabitants of the fouling population.

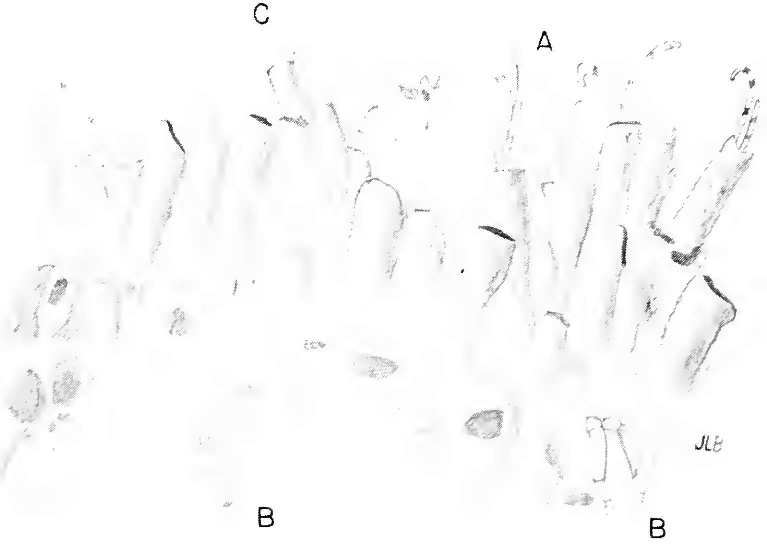

FIGURE 2. Detail of the peripheral edge of a silty fouling mass built by a bloom of the polychaete *Polydora* sp. (A). At first, the tubes are quite regular in position. Later (2 months in this case) many of the polydoras perish, the center surface of the colony is occupied by the amphipod *Corophium acherusicum* (B), and the tubes are more or less immersed by peritubicolous material. Occasional amphipods, *Jassa falcata* (C), inhabit the mass. In life, under the microscope, the assemblage provides a scene of constant activity—the waving palps of *Polydora*, the jerking activities of *Corophium* moving in and out of the holes, and the waving motions of *Jassa*. Colors in life are dull and the near imperceptibility of the several organisms is striking. x 5.

THE OTHER FOULERS

Polychaetes were next to the amphipods in abundance. They were represented mainly by the species *Polydora (Carazzia) paucibranchiata* Okuda, *Hydroides norvegica* (Gunnerus), *Podarke pugettensis* Johnson, and *Capitella capitata* (Fabricius). The only other important early settler was the tunicate *Ciona intestinalis* (Linné), occurring sporadically, but in terms of biomass exceeding all other animals combined. At Station P about 100 adult tunicates with a volume of over four liters were present on the 16-week block. However, this tunicate was not a conspicuous member in the climax fauna on old pilings in 1950 and 1951. The densest covering of animals, more than 400 per square inch, occurred at Station H, where no tunicates were present. The amphipods appear to comprise a substantial part of the biomass in Los Angeles-Long Beach Harbors, but detailed examination of the climax fauna is required to verify this.

Sparse early representation in the harbors was shown by hydroids, barnacles, mussels, limpets, other mollusks, a few rare species of polychaetes and amphipods (Barnard, 1951), bryozoans, sea anemones, *Epinebalia* sp., etc.

The early abundance of amphipods on test blocks is remarkable. It is the general understanding of students of fouling that the attachment of amphipods is dependent upon protective niches and crevices provided by sessile organisms (Milne, 1940, p. 69-70). This is probably true for non-tubicolous amphipods and other crustaceans, but the tubicolous amphipods provide their own shelter. One must assume that predation by fishes and other carnivores on the settling amphipods is high, although in turbid waters predation may be relatively ineffective because of the reduced visibility or nonsuitability of the waters for fish life.

RESTRICTION OF POPULATIONS BY UNFAVORABLE ENVIRONMENT

The range of water temperature in LA-LBH was not a limiting factor for most marine animals which are known inhabitants of arid-type estuaries. According to Woods Hole Oceanog. Inst. (1952, p. 11), marine fouling grows rapidly at temperatures between 80 and 90 degrees F., but is restricted by temperatures above 100 and below 60 degrees F. Indirectly, high temperatures may restrict animals by decreasing the solubility of oxygen. The populations at Stations A,C,D, and Q were small or absent, probably due to the lowered dissolved oxygen caused by higher temperatures and pollutants, both organic and in the form of hydrogen sulfide generated by bottom sludges.

During the heavy fish canning season in the late summer and early fall of 1950, Stations J and H were heavily polluted by a chalky waste water, the oxygen content falling to zero. By the following spring these stations were infested abundantly by foulers, indicating no lasting effect of the reduced oxygen supply.

RELATIONSHIP OF TURBIDITY TO FOULERS AND BORERS

In areas of adequate dissolved oxygen, the suspended solids in the sea water appeared to play a major role in determining the variability of the fouler populations. Adequate turbidity data are not available to explain each case of fouler occurrence, but selected examples are listed in Table 5 to show the extremes of fouler and borer populations in relation to turbidity. In relatively clear waters of turbidity grade 3, flexitubicolous amphipod and polychaete foulers were scarce, while boring organisms such as *Limnoria* were abundant. When foulers occurred on blocks suspended in clear waters, they consisted primarily of barnacles, serpulids (*Hydroides*), and tunicates. In turbid waters (grades 1 and 2) fresh surfaces were quickly infested by tubicolous amphipods and polychaetes, while early borer occurrence was negligible.

TABLE 5

Abundance of Foulers and Borers at Selected Stations in Los Angeles-Long Beach Harbors, on 16-Week Blocks Collected August 17, 1951

Station	Foulers	Borers	Turbidity grade
F	1,568	11,086	3
R	74	3,041	3
D	5,173	3	1
H*	22,345	5	2?
J	7,739	0	2
P	14,056	17	2
L	12,503	52	2

* Measured turbidity was grade 3 for three tests (see Table 2), but 14 visual observations by the writer in 1950-51 indicated the average was grade 2.

Turbid waters bear organic and mineral particles, useful to foulers for tube construction and food, but probably not available to most boring organisms which eat wood and in so doing construct their own shelter. Planktonic organisms thrive in some polluted waters, providing a food source for filter-feeding foulers (Sundene, 1953). The lack of early borer infestation in turbid waters suggests that they are restricted by the protective mat of tubicolous foulers which covers the fresh wooden surfaces. Heavily fouled surfaces also harbor species of predatory polychaetes, some of which eat *Limnoria* (Reish, 1954).

The ecological balance of factors favoring foulers or borers is a delicate one. In Los Angeles-Long Beach Harbors this is evident on the one hand by the presence of inactive wood borings which have been covered by foulers, and on the other hand by those areas which have been infested with destructive borers after water quality had been improved by better waste disposal practices and dredging. The balance changes seasonally in waters subjected to freshwater flushing (Milne, 1940, p. 76). The seasonal winds, with their influence on water turbidity, may also have an effect on this ecological balance.

It may be practical to consider that temporary wooden structures erected in clear, restricted harbor waters might be protected against borers for a period of six months to a year by changing the conditions to favor mat-forming fouling organisms. This might be accomplished by roiling the water and releasing small, continuous supplies of organic food particles, such as cannery waste and macerated garbage. The tubicolous foulers would be supplied with turbid water rich in food, resulting in a covering mat protecting the wood against the boring organisms. This type of operation necessarily would be closely regulated by public agencies concerned with marine pollution.

COMPARISON WITH OTHER HARBORS

The fouling composition in LA-LBH contrasts strongly with that of Newport Harbor, a few miles downcoast, and from other harbors of the world (Woods Hole Oceanog. Inst., 1952). The writer has studied the Newport piling fauna (unpublished data) and finds it accurately described by Scheer (1945). The waters of Newport are clearer than in most of LA-LBH and pollution sources are minor. Newport Harbor is protected by a narrow inlet, restricting stirring of the bottom by wave action. Scheer (1945) found that test plates showed early prominence of hydroids, *Ectocarpus*, bryozoans, and *Eupomatus* (serpulid). The writer examined several test blocks exposed in various parts of Newport Bay and found only a few tubicolous amphipods. Occasionally, numbers of *Elasmopus rapax* Costa, a large nontubicolous amphipod, were found clinging to the blocks. Scrapings of pilings showed that tubicolous amphipods were not abundant. Nontubicolous amphipods such as *Stenothoe*, living among flourishing hydroid colonies, and leucothoids, living in sponges and tunicates (Barnard, 1955a), were important settlers, unlike the situation in LA-LBH.

This finding adds further weight to the evidence that flexitubicolous amphipods and polychaetes are detritus feeders, flourishing only in those very turbid waters carrying organic detritus useful as food.

Inconsistencies in closely situated faunas of pilings and buoys, as mentioned by Scheer (1945, p. 104), depend in measure on the season of immersion of the attachment surfaces. Thus, a surface exposed prior to a reproductive peak of *Ciona* and already covered with tubicolous amphipods may be unsuitable for the *Ciona* larvae. Undoubtedly, day to day and week to week changes in the environment are common in harbors. The writer has observed spillage of gasoline during the refueling of boats, which conceivably could coincide with the settling of sensitive larval organisms on fresh surfaces. Moving ships in a harbor may create waves and currents which waft larvae from moderately distant sources to new areas. These and other examples may be theorized to explain unaccountable results in test exposures. What must be pointed out is that larval settling organisms are sporadic, while tubicolous amphipods, which brood their young, migrate continually, due to the mating phenomenon. Thus, a relatively continuous settling pressure is maintained by the tubicolous amphipods and is one factor in their success as fouling organisms.

SUMMARY

1. Apart from periodic blooms of larval organisms, such as hydroids and tunicates, coincident with the immersion of fresh surfaces, amphipods and polychaetes consistently were the earliest and most abundant settling metazoans in Los Angeles-Long Beach Harbors.
2. The tube-building amphipods and polychaetes covered the surfaces of some test blocks, building layers of tubes and forming thick, silty fouling masses on pilings and ship bottoms. These are called mat-forming fouling organisms.

3. Tubicolous amphipods were most abundant in those waters of the harbor having a high turbidity coincident with favorable dissolved oxygen and temperature conditions.
4. Tunicates, serpulids, mussels and other large sessile organisms were the foulers most obvious to the naked eye, but in some climax faunas amphipods and polychaetes may be a sizable part of the biomass.
5. Large early populations of fouling organisms apparently restrict the early ravages of borers such as *Limnoria*. Thus, borers are more prevalent in clearer waters.
6. Consideration is given to a practical method of restricting borers from temporary uncreosoted wooden structures by providing an artificial turbidity, composed of food and silt, which would favor the formation of protecting mats of foulers on fresh surfaces.

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ALBINISM AND AMBICOLORATION IN THE CALIFORNIA HALIBUT *(PARALICHTHYS CALIFORNICUS)*[1]

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During the summer of 1956 two unusually pigmented California halibut *(Paralichthys californicus)* were taken by fishermen in southern California waters. These fish were presented to the Department of Fish and Game for examination and study. One of the fish exhibited almost complete albinism and the other was ambicolored (pigmented on both sides).

Although Department personnel previously had never observed an albino California halibut, ambicoloration has been noted upon a number of occasions. The capture of either type of variant always arouses considerable interest among the sportfishing enthusiasts in the immediate vicinity and the fish is usually sent to the Department along with a number of questions regarding its rarity, edibility, ancestry, and general state of health.

[1] Submitted for publication August, 1957.

TABLE 1

Counts and Measurements Made Upon Three California Halibut

	Albino "right-handed"	Ambicolored "left-handed"	Typical "left-handed"
Measurements:*			
Standard length	282	320	370
Total length (to upper lobe of caudal)	120.9	121.2	120.5
Head length	27.3	28.4	26.8
Fleshy orbit (lower eye)	4.4	4.0	3.8
Fleshy interorbital width	2.8	2.9	
Snout length (to lower eye)	6.4	6.6	
Maxillary length	13.1	12.0	11.9
Body width (greatest)	39.5	42.2	37.0
Caudal peduncle width	9.5	10.3	8.6
Pectoral fin length (eyed side)	13.1	13.1	11.9
Ventral fin length (eyed side)	7.8	6.9	7.0
Snout to dorsal insertion	6.5	10.0	
Snout to anal insertion	32.7	34.0	
Snout to ventral insertion	25.7	24.6	
Snout to pectoral insertion	26.6	26.9	
Counts:			
Dorsal rays	69	71	68
Anal rays	53	54	54
Pectoral rays	I, 10	I, 10	I, 10
Gill rakers	7+20	9+19	9+22

* Standard length is given in millimeters; all other measurements are presented as percentages of standard length.

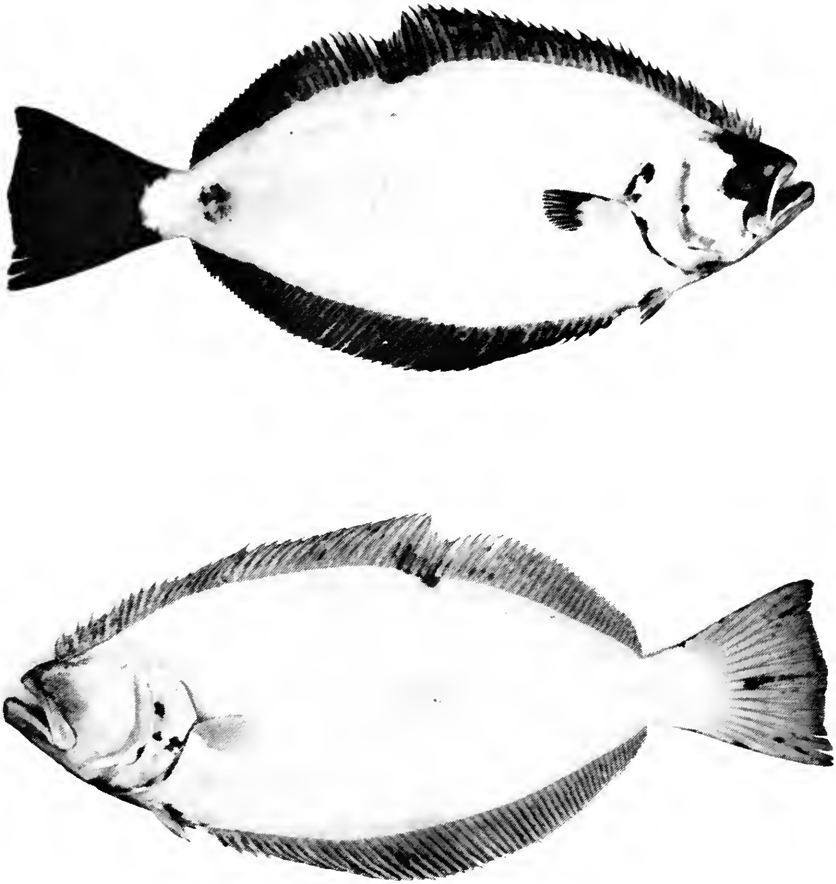

FIGURE 1. Eyed side (top) and blind side (bottom) of albino California halibut, 282 mm., standard length, taken at Seal Beach, June 24, 1956. *Photograph by Jack Schott.*

The albino specimen, a female with eyes on the right side (Figure 1), was taken on June 24, 1956, from the pier at Seal Beach by Mrs. Margaret Virzi of that city, and was given to "Tommy's Bait and Tackle" shop to be forwarded to the California State Fisheries Laboratory, Terminal Island. The bulk of the body was completely unpigmented. There was, however, some pigment on the snout, pectoral fins, and tail on the eyed side. In addition, the caudal peduncle was normally pigmented and the dorsal and anal fins were piebald (spotted) on both sides. This is the first albino halibut of this species ever observed by personnel of the California Department of Fish and Game. According to Norman (1934) and Ginsburg (1952), varying degrees of albinism are not uncommon among flatfishes. To our knowledge, however, the condition has not been reported previously for the genus *Paralichthys*. Although the fish appeared normal in all other respects, counts and measurements were taken (Table 1).

Just three weeks later, on July 10, 1956, the completely ambicolored individual was taken. This fish, a female with eyes on the left side, was caught on hook and line by Frank Remely, Jr., at the Balboa Pavilion on Newport Bay, California. It was forwarded to the California State Fisheries Laboratory at Terminal Island by the Balboa Angling Club. As in other flatfish in which complete or nearly complete ambicoloration has been observed, several deviations from normal symmetry were noted. The most outstanding deviations were the incomplete migration

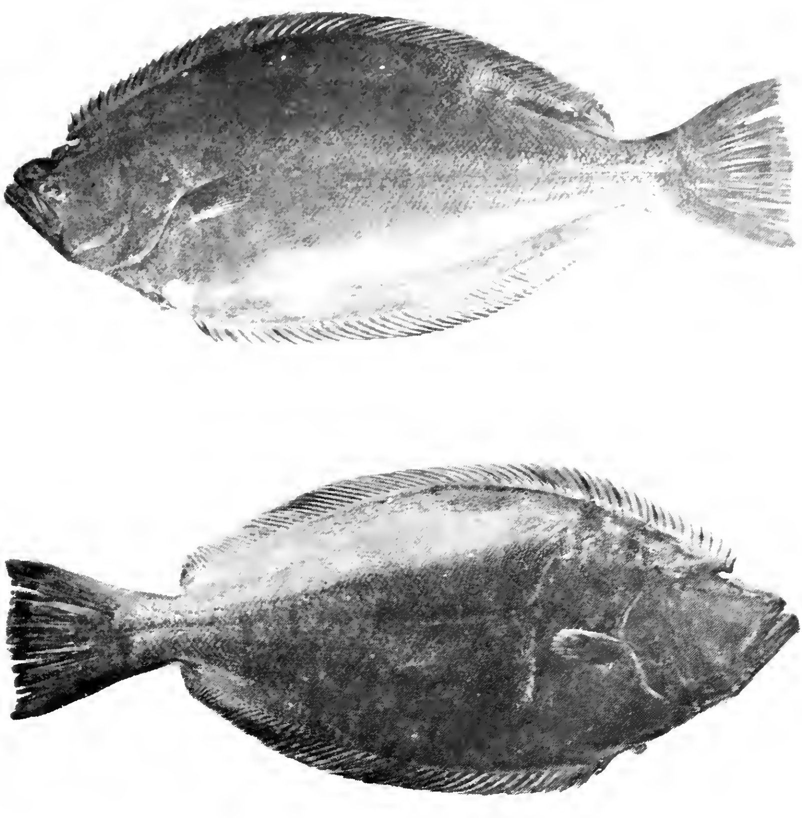

FIGURE 2. Eyed side (top) and blind side (bottom) of ambicolored California halibut, 320 mm., standard length, taken at Balboa Pavilion. Note fleshy anterior projection of dorsal fin over upper eye, which has failed to migrate completely across head to left side. *Photograph by Jack Schott.*

of the upper or right eye and an anterior fleshy hook or lobe formed by the dorsal fin (Figure 2). Counts and measurements were made on the ambicolored specimen for comparison with those of the albino fish and a "left-eyed" halibut with normal or typical coloration (Table 1).

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STARVING THE CONDORS?[1]

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Seemingly almost every known expedient for saving the California condor (*Gymnogyps californianus*) from extinction now has been employed. A special refuge has been set aside for the birds, laws for their specific protection have been passed, and considerable publicity has been given to their plight. It has even been suggested that superannuated horses and other animals should be slaughtered in order to assure a food supply. In spite of these provisions for their perpetuation the condors are barely holding their own and, as a matter of fact, they may be imperceptibly losing ground.

The known shrinkage of their range throughout post-Pleistocene times serves to indicate that they were doomed to extinction even prior to the arrival of the white man, with his superior weapons. There seems to be little doubt that whatever effect man, including the Indians, may have had on these birds, it was probably limited to mere acceleration of a process that was initiated many thousands of years ago. The white man has probably been the chief agent of destruction for only a little over a century. In other words, man's total effect has been relatively small insofar as the remote historical picture is concerned, even though it has probably been very great in recent times.

Irrespective of the basic cause of the condor's decline it seems probable that we are witnessing an acceleration of the final stages of extinction of the world's largest flying birds. If we are to allow even a few more generations of human beings to have the esthetic pleasure of observing these birds as they soar through the skies or enjoy the inspiration that comes from even closer and more prolonged association, we will have to take all possible steps to insure their survival for as long as possible.

Seemingly, protection of the individual bird is about as effective as practical measures can achieve. The establishment of the condor refuge assures the birds a considerable degree of peace and privacy for rearing their young. Supposedly, food and water supplies are adequate, even though there are suggestions that supplemental feeding might be a useful practice not only to insure against starvation but also to prevent their wandering to ranches where irresponsible persons with firearms, or poisoned carcasses of animals, might bring about death of either adults or young.

A more effective way to provide the condors with increased water supplies and to feed them in their home ranges with the variety of

[1] Submitted for publication November, 1957. The publication of this article in *California Fish and Game* does not mean that the California Department of Fish and Game concurs in all the conclusions of the author. The Department does believe that the article is provocative and merits the consideration of conservationists.

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food that most animals seem to require, is available and relatively simple and inexpensive. Theoretically, at least, this is practical or would be practical if public support would provide the necessary impetus to its implementation.

It seems almost certain that for the past four decades we may have been increasingly starving our condors by preventing them from getting access to what food might otherwise be available, as well as by reducing the productivity of the lands that produce their food.

If the condor refuge was completely covered by mature chaparral, in order to feed the birds would be forced to fly to the margins of their range, where they would be subjected to danger from poison and firearms. One has only to visit the sanctuary's lower reaches, below pine tree levels, to discover that even if food animals were dying in considerable numbers over considerable areas the condors would be unable to land near the carcasses or crawl through the brush to gain access to the food. Even if they succeeded in reaching food and managed to gorge, the take-off problem through the tall brush would be even more serious.

I know of no information on condor killing by predatory animals but it requires little stretch of the imagination to visualize the predicament of a gorged, even an empty condor, competing with other predators while attempting to crawl through brush en route to or from a carcass. In the first place, extensive walking or burrowing through brush is foreign to condors, but if hunger did force them to land in some small nearby open spot, their departure without ample take-off lanes would be impossible. They would be exceedingly vulnerable to injury on take-off and landing, as well as to predators defending carrion.

Once fire has destroyed the chaparral, landing and take-off areas are available over most of the mountain sides. This may be especially important to birds that are carrying an extra burden of food for their young. Furthermore, a downhill rather than a level ground take-off is advantageous because of the favoring gradient. Possibly of equal importance to the birds is the fact that the prevailing daytime wind currents ascend the ridges and so additionally favor easy take-off. The importance of thermal air currents to condors seems to be well known and their presence is believed to determine the time at which they take flight from their roosts on normally calm days.

In addition to recognition of the advantages of burned-over versus nonburned chaparral with respect to landing, walking to food, and take-off, it is also necessary to bear in mind the vastly increased faunal resources that accompany revegetation of burned-over areas. The increased carrying capacity during revegetation of chaparral areas has not been adequately measured, but it is known that the deer-carrying capacity of mature chaparral is low and that additional forage in recuperating burned areas will allow a severalfold increase in numbers of deer. From personal observations the carrying capacity for "rabbits," especially the jackrabbits (hares), may be enhanced as much as 20-30 times, and even this estimate may be a moderate one, since jackrabbits shun genuine chaparral and require virtually open country. After burning they enter areas not previously occupied, hence their increase might start from zero initially and increase by factors even larger than 30 (Sweeney, 1956).

Because the number of predators is also related to the carrying capacity of an area, the increase in herbivores would result in increased numbers of these animals, and since they also are presumably acceptable food to condors, the birds would profit by an almost entire food chain.

Areas near or within the condor refuge that have been swept by accidental fires, as near Santa Barbara in 1955 and 1956, would furnish particularly interesting study locations where condor activity might be correlated with revegetation and the successive faunal changes. As the chaparral regains ascendancy and once more intereferes with condor landings and reduces the carrying capacity of the area, the birds would be expected to move elsewhere. A five- to seven-year study of extensive chaparral burns and condor feeding areas should settle the question of whether conditions subsequent to chaparral fires would really provide better survival conditions for condors.

Without having conducted actual census studies of sample areas both before and after a burn, it is only possible to guess at the total chronology of changes that would take place, but personally I would venture to surmise that brush and cottontail rabbits and hares would achieve their maximum density by about the third to the fifth year following a burn, with coyotes, foxes, and bobcats following about the same pattern somewhat behind the herbivores. The rate of repopulation would be determined in part by the distribution and size of the burned area and the distribution and size of unburned patches from which faunal repopulation would have to come (Longhurst and Leopold, 1952).

In addition to the greatly enhanced supply of vegetation that follows burning of the chaparral, there is an even more surprising rehabilitation of underground water supplies that is expressed by renewed spring flow and an extension of stream flow later into the summer or even throughout the drought months (Biswell and Schultz, 1957).

A combination of diversity in the diet, more abundant food, and easily accessible water supplies may be all that is required to perpetuate the birds. I believe that the comparative ease with which we observe condors feeding on large animals such as deer has blinded us to the fact that they may prefer or at least thrive better on the more abundant, hence more continuously available, supplies represented by small dead animals than on larger species.

The virtually uncontrollable wildfires that sweep through our chaparral areas during early fall, but particularly those that happen to coincide with the violent föehn or Santa Ana[2] winds of late autumn, move so rapidly and leave so few patches of unburned areas that, excellent as the faunal regeneration may be, it is undoubtedly retarded and hence not to be compared with the beneficial effects that could result from controlled spot burns which would be repopulated from shelter on all sides.

Because of the uncontrollability of fires driven through the superdried chaparral by föehn winds and the virtual inevitability of sporadic

[2] Various spellings are prevalent.

wildfires soon or later sweeping throughout an entire chaparral belt, it is inevitable that careful thought and research should be given to the advisability of controlled burning, so that only minimum fire damage will result. Enough tests have been made in northern California to justify the belief that properly conducted control burning might yield real and permanent benefits to watersheds and wild life.

Only under the most extraordinary circumstances will the chaparral burn during the wet winter months and even during the spring season it will seldom carry fire, but during late summer and fall it becomes a nightmare hazard to firefighters, farmers, and suburban residents who live at the margin of chaparral. Because there are these two seasons, of no fire and wildfire, we can only conclude that between spring and summer there must be periods when control would be simple and fire damage slight. Research should be able to provide directions for controlled burning under optimum conditions.

The implication here is that by deliberate use of fire in the chaparral belt it might be possible to not only obtain maximum production of wild life and perpetuation of the condors, but at the same time virtually insure against escape of the uncontrollable late fall wildfires.

So radical a suggestion will of course bring to mind the supposedly unmitigated horrors of blackened mountains, miles of scenery characterized by the bleakly upraised charcoal-black tree stubs, and inevitable sequelae of mud and flood damage. All of our esthetic feelings resulting from indoctrination in forest conservation are revolted at the thought of burning, but to be honest with ourselves we should be willing to re-examine each of these supposedly inevitable consequences of brush fires. To do so only requires that we, personally, take the trouble to observe the sequence of events following several of our local fires.

From the esthetic standpoint the scars left by a savage autumn fire are indeed black. For weeks charcoal and ash blanket the ground in a mournful pattern of black and white. Even the rains of early fall and winter do little more than sharpen the contrasts in scenery. A drive through such an area is a most depressing experience for any lover of nature, a fact that probably explains why most of us are unaware of what follows—we simply do not return for another look during the spring months.

The amazing tenacity of life exhibited by most if not all species of chaparral plants attests to their ages-long testing and selection by fires and supports the casual comments of early explorers who stated that during certain seasons of the year vast fires raged unchecked through California's valleys and foothills.

Long before the first rains fall, chamise (*Adenostema fasciculatum*), laurel sumac (*Rhus laurina*), toyon (*Photinia arbutifolia*), redberry (*Rhamnus crocea*), elderberry (*Sambucus coerulea*), and a host of other plants show many tender green root-crown shoots around the bases of most of the scorched and blackened stubs. As soon as these tender and succulent shoots put in their appearance, deer, rabbits, and rodents move into the blackened areas to enjoy the new delectable and nutritious source of food and moisture. An August fire in the Santa Monica Mountains near Los Angeles, for instance, provides the only abundant supply of succulent feed available in October, November, and December where, unless there have been early rains, all other fodder is harsh, bitter, repellant, and low in moisture content.

Soon after January, depending on the arrival of the first rains, the burned-off hillsides turn tender green with myriads of newly sprouting plants, but this rebirth is most notable where the fires had least fuel and so were not as intensely hot. This is particularly true where only grass was burned, for here the magic of rebirth is most complete and dramatic. Wherever chaparral has been growing for the longest time and formed the deepest thickets and the heaviest accumulation of dead twigs and leaves, i.e., where soil and moisture have been most favorable and where the longest time has elapsed since a previous burn, the damage is most serious and it may require even a second or possibly a third year to reseed and regrow a cover of annual plants.

During May, June, and into July the annual flowers blossom in unexpected profusion of color, species, and fragrance. Throughout the area an entirely new source of food supports an amazing multiplication of succulent, juicy insects, so that on a warm still day there is a continuous humming from all sides and even the aereal pathways seem bursting with life. By comparison, a thick mature stand of chaparral seems positively lifeless. One of the results of this radically new food chain is an increase in number and diversity of bird life and it is surprising that this result follows as early as the spring immediately following a fire. Such a delightfully colorful, fragrant, and biologically active an area should become the focal point of attention by local bird-watchers but unfortunately the memory of the burn-sears, or the prevailing belief that there is only ugliness, discourages visits.

From a purely esthetic standpoint even a first-year burn which has had normal rainfall rapidly becomes one of the most satisfying places in which to spend a day in the field, but this is particularly true of the warmer, low elevation chaparral. Higher up in the mountains a superficial viewing suggests a longer delay in recuperation of flora and fauna. In these lower areas it is a constant source of surprise to see the speed with which root-crown shoots of many species send up their spears of green foliage rapidly to camouflage the blackened stumps of their parents. By approximately a year after a burn, shoots of some species, notably elderberry, will reach a height of 10 or more feet. On reflection, we should expect this rapid growth in fire-adapted species, for only the top is destroyed by fire and thus the proportionately enormous root area pours all nutriment into the new growth. It is as though the plant merely had been pruned back to concentrate all of the root vigor in a few shoots.

From two years onward after a burn, for each plant or animal destroyed there will be several times as many replacements, most of them alive and flourishing only because the fire had temporarily suppressed the dominating strength of the chaparral and given the new generation a chance to live. Their days in the sun will be brief, however, for in 10 or so years the tough, resilient chaparral will once more have gained ascendency and so will crowd out the more delicate plants and all the animals that flourished in them.

According to the gospel of many California conservationists, the specter of fire is supposedly invariably followed by dangerous floods and mud. This is so deeply ingrained a belief that to even question it is heresy, and to argue that floods are not everywhere and always a consequence of fire is to evoke a surprisingly violent and emotional reaction.

Some years ago this writer believed in the virtual sanctity of this common conception and in a determined effort to obtain photographic documentation of erosion and flood damage, a pictorialization of devastation that would be convincing to a class in natural history, he marked certain vulnerable channels of runoff below fresh burns. After each heavy rain he returned to take convincing photographs of the damage. Each new burn was watched but each year the visually demonstrable damage was so slight that to have shown photographs of it would have been considerably less than convincing to an unbiased student! This is not to say that fires do not for a time accelerate erosion and floods and produce concommittant damage to soils. Many do, and in some areas this acceleration is notable, but it was interesting to observe that during these years one of the worst cases of mud flows, floods, and highway and other damage took place where the chaparral had been untouched by fires for a good part of several preceding decades.

Much research of an experimental nature needs to be done. Observation alone will not suffice. It is abundantly clear that in some areas, on some soils, the classical predictions may not be borne out either in part or in whole, while on other soils or slopes, no visible damage will result. What is most needed is experimentation that will substitute, if possible, native grasses and low-growing native shrubs for tall chaparral. Also needed is a study on the relative effects of protecting chaparral for many decades, so that when inevitably it does burn, its detritus will create so hot a fire that the soil is virtually sterilized and the ugly scars are slow to heal. It well may be that frequent burning despite the resultant initial exposure and vulnerability of the soil may produce less cumulative damage than a single intense fire.

Grassy slopes or those covered with only low-growing sagebrush and similar plants recover most rapidly and the vegetation cover seems to furnish perfectly adequate—in some observations even superior—protection against beating rain. Here again aggressive experimental studies are needed.

In conclusion, intelligent wildlife and water conservation as well as protection from fires and flood and damage in California can only be achieved by taking a new look at our old shibboleths which hold that everywhere and anywhere, chaparral fires are unmitigated disasters. To discover where, when, and how to take positive action rather than purely defensive measures will require the moral support of the public as a whole. No conservationist would care to attempt extensive experimentation without a measure of firm public backing.

In the final analysis erosion and floods are the mighty forces that have always operated to enrich the valley floors and ultimately to level even mountains. Our chief conservation mistake is in ignoring this inescapable fact and to have built houses, towns, roads, and highways in the pathways of these occasionally irresistible forces. The ultimate cost of attempting to suppress natural phenonema, including brush fires, may well mount far beyond what costs would have been had we recognized them and avoided conflict or even worked with the forces of nature.

Quite possibly one of the tragic victims of our conservation activities may be one of our most prized objects of conservation endeavors, the condor.

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MARKING DEER WITH BELLS[1]

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INTRODUCTION

Belling is being used in a study of deer movements on the San Joaquin winter range in Madera County as a method of marking in order to determine location and individual identification. This work began in 1955 and is continuing as part of a cooperative investigation of deer range improvement conducted by the University of California, California Department of Fish and Game, and the United States Forest Service.

Hahn and Taylor (1950) reported using bells successfully for marking in Texas. Elsewhere in California the Department of Fish and Game is currently using bells in separate deer studies in the McCloud Flats area of Siskiyou County, the Doyle and Petersen mountain areas of Lassen County, and other areas, and Longhurst[2] is using them at the Hopland Field Station.

ACKNOWLEDGMENTS

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MARKING DEER

During the winters of 1955-56 and 1956-57, along the northwest side of the San Joaquin River between Lion Point and the San Joaquin Mines, 260 deer were trapped and belled. These are California mule deer (*Odocoileus hemionus californicus*). For individual recognition, different combinations of bell size, colored designs on bells and ear tags, and placement of ear tags were used. These were supplemented by dying the leather bell straps, tying colored nylon ribbons to the straps or chains holding the bells, and notching the ears. Ashcraft[3] has successfully used pieces of plastic, three inches wide and $\frac{1}{16}$-inch thick, in various shapes and colors, attached to a chain. Progulske (1957), though

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[2] Personal communication with William Longhurst, Hopland Field Station, Hopland, California, June, 1957.
[3] Personal communication with Gordon Ashcraft, Calif. Dept. of Fish and Game, March, 1957.

not using bells, marked deer with plastic-covered, leather collars two and one-half inches wide marked with combinations of five colors and five designs.

Ten sizes of turkey and sheep bells were used, ranging from one to two and three-quarters inches in height and from 0.7 to 6.2 ounces in weight. The large bells were used on bucks and does and the small ones on fawns. Each size has a different tone. The maximum distance at which bells could be heard varied from 50 to 800 yards. Audible range is affected by the activity of the deer and by vegetation, terrain, and weather, in addition to the size and type of bell. The weight of the bell appears to be directly related to the audible distance.

The designs painted on the bells are shown in Figure 1. The most easily recognizable color combinations were black on white for long distances and in poor light, and black on orange in dense brush. Red and green, each in combination with black or white, were also used.

Success in marking requires that painted colors and designs remain recognizable for a number of years. Painting the copper-coated surfaces found on most sheep and turkey bells presents a problem. Bells used the first winter were cleaned with a metal prep, then painted with three coats of synthetic enamel. After eight to 15 months, five out of 71 bells were chipped badly enough to make recognition difficult, and many more were chipped in varying degrees. None was completely unrecognizable. During the same period, colors had not faded. Bells used during the second winter were painted similarly but were treated first with a baked-on copper-etching compound. Whether this additional treatment increases the durability is not yet known. Longhurst painted with Boysen "Plasolex" plastic paint after first buffing with a rotary steel brush and then priming with zinc chromate. He reports that, because this type of paint never completely hardens, chipping was nearly eliminated.

Application of paint by dipping causes bell tone to be muffled for two or three weeks or until after paint has been worn from the clapper.

Leather straps, light chain, and nylon ribbon have been used to hold the bells. Besides the lower cost, chain has the advantage of being permanent. Retrapping showed that 4 out of 29 straps had broken before 8 to 15 months had elapsed. This loss will accelerate with time. Brass toilet chain, used by Ashcraft, weighs 1.0 ounce as compared to 2.8 and 1.0 ounces for two types of straps used. When using chain, precaution must be taken that the bell hangs perpendicularly, so that the clapper, in order to strike readily, hangs free of the bell surface. When additional marking devices are attached to the chain, the bell should not be able to slide on the chain; otherwise, the devices may change position and obscure the bell. Nylon ribbon was used for holding turkey bells on fawns. It is extremely light in weight and is nonpermanent. Nonpermanency was desired with fawns so that the strap would be gone before they outgrew it. This ribbon is available in a variety of bright, fade-resistant colors.

The most critical consideration in belling deer is the length of strap or chain to be used. Insufficient slack creates the danger of constriction during future growth. If excessive slack is allowed, the belled animal can place a foreleg or even hook the lower jaw inside the strap or chain. Study of this problem has led to the following conclusions. It is

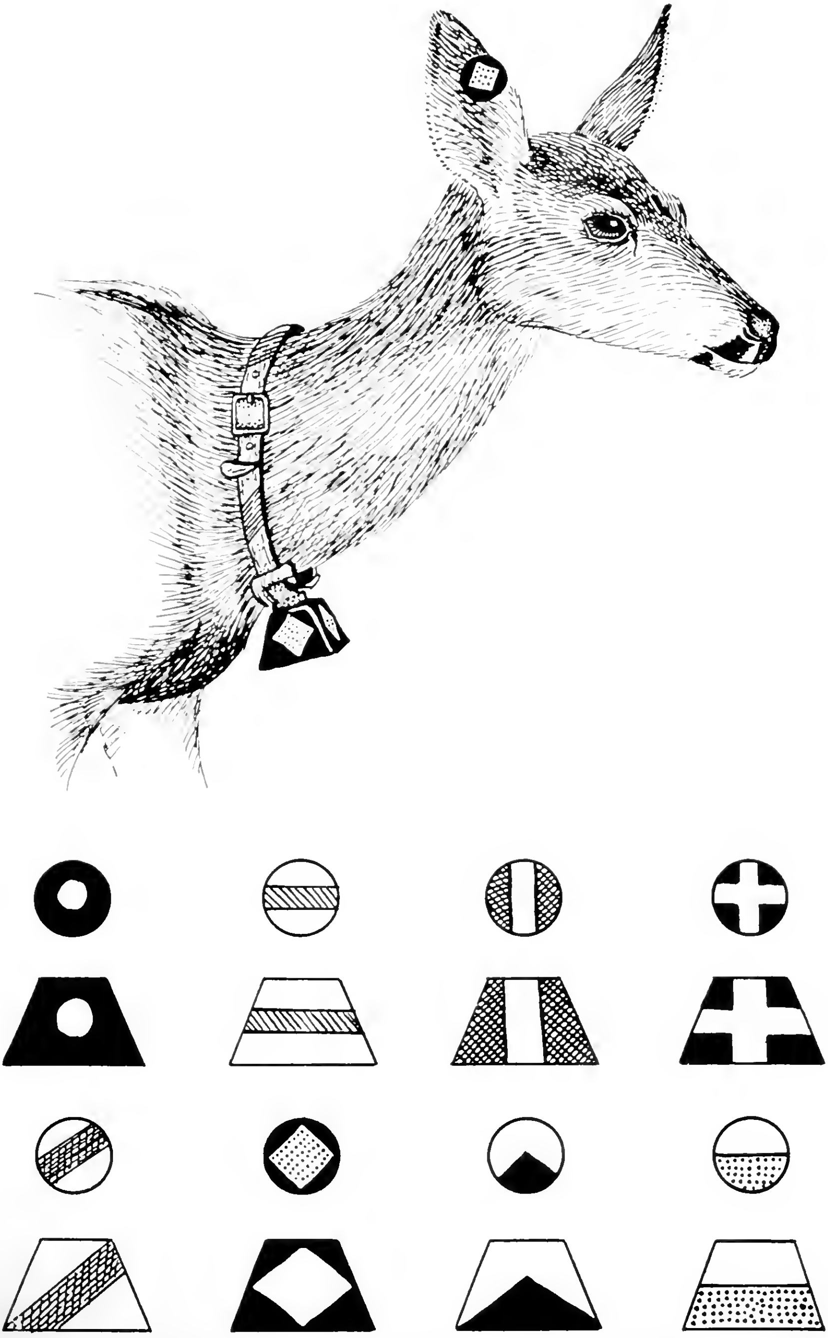

FIGURE 1. Examples of designs on bells to facilitate identification of individuals. Note matching ear tag and bell on deer. *Drawing by G. M. Christman.*

not advisable to bell fawns unless they are close to adult size. Yearling and adult does may be safely belled because future change in neck size is negligible; the recommended strap circumference is 16.5 inches for does of this herd. In bucks, the circumference of the neck at its narrowest point may vary from 11.5 inches in yearlings to 22 inches in fully developed individuals which are rutting. It has been concluded that, for safety, slack distance (the distance from the underside of the narrowest point of the neck to the top of the bell) should not exceed three and one-half inches. Therefore, we believe that bucks should not be belled with a permanent device before the age when growth is nearly complete. Progulske (1957) concluded that collar circumference for mature white-tailed deer (*O. virginianus*) in Missouri should be 25 inches in bucks, and 20 to 21 inches in does, and that very young deer should not be collared.

An alternative method which should insure the animal's safety is the use of a nonpermanent material such as ribbon. Also, chain or leathers straps could be used with safety if fastened with a weak link, such as a hog ring, which would come apart under any unusual pressure. Ashcraft [4] has used hog rings on all deer belled and he states that, besides their safety value, they simplify the deer handling operation.

EFFECTS OF BELLS ON DEER

Physical Effects

No over-all difference in the condition of deer which had worn bells for eight to 15 months was noted upon retrapping. During the two winters of observation, three belled deer were found dead of unknown causes. The ratio of belled to unbelled deer found dead does not seem to differ markedly from the comparable ratio in live animals. Had either winter been more severe, with a resultant high deer mortality, the effects of bells might have been determined from a differential death rate in belled and unbelled deer.

After one year, the majority of belled deer showed pelage loss from the top of the neck due to the sliding action of strap or chain. Such loss would be disadvantageous to an animal in cold weather, but it is not known to what degree.

A slight stiffness while running was noted in the forelegs of three belled bucks. No explanation for this condition is known.

Behavioral Effects

Most deer appear frightened when first belled. Upon release after belling, two deer were observed to run about a mile before turning back. However, both belled deer and their unbelled associates seem to quickly adjust to the new condition. The relationships within maternal or feeding groups were not disrupted by the belling of one or more members. Only twice were unmarked deer observed to be alarmed by the presence of bells. Observations during the rut showed normal courtship behavior. Three belled bucks were seen in pursuit of unmarked does, and four belled does were seen being chased by bucks. An attempt by a buck to mount a belled doe, though not during the rut, was ob-

[4] Personal communication with Gordon Ashcraft, Calif. Depart. of Fish and Game, March, 1957.

served. Whether our belled does were bred remains to be seen. Longhurst reports observing a number of pregnant belled does.

Susceptibility to Predation

No evidence of belled deer being more susceptible to predation has been obtained. In a brief review of the literature, no reference to a differential predator susceptibility in belled stock animals was found. H. Nelson Elliot,[5] who has worked in predator control for 25 years, wrote to the author that belling of livestock, especially sheep, has been used in an attempt to discourage predators. Having received a number of reports on these programs, he concludes that bells may discourage coyotes and mountain lions temporarily, but eventually the predators lose fear of the bells, as evidenced by attacks on belled animals. No mention of the possibility of belled stock being more susceptible to predation was made.

Susceptibility to Hunting

During the hunting season following the first winter's trapping, eight belled bucks out of a possible 31 were reported taken by hunters. On the basis of retrapping and observations after the season, it is suspected that more were killed than were reported. As will be pointed out below, it was many times easier to locate and to approach belled deer than unbelled deer for sight observation. If the same criterion applies to hunting, which is a reasonable assumption, then the hunter's chance of killing a deer should be greater if it is belled. This assumes that the hunter will shoot the first legal animal he encounters. However, some hunters might bypass the opportunity to shoot a belled deer for a number of reasons. It is hoped that future data will allow us to measure susceptibility differences between belled and unbelled deer.

USES AND TECHNIQUES IN RESEARCH

Observational Success

Success in observing and identifying belled and unbelled deer as calculated from the first winter's data is shown in Table 1. The unbelled deer were marked only with ear tags. Results in two areas were compared: Lion Point has high vantage points from which a large portion recently opened by burning may be viewed; Kinsman Flat is relatively level and covered mostly with dense brush. Unbelled individuals seen in the company of belled deer are kept separate in the table, because their being seen was somewhat dependent on the presence of bells. Thus, this group is excluded from the unbelled sample used in the following calculation showing the efficiency of bells. Of the total number released, the percentage which was observed and identified was calculated for belled and unbelled deer in both areas. This figure, multiplied by the average number of observations made on each individual of the respective groups, gives a measure of observation success. These measures, when compared directly, show that belled individuals were located and identified 14 times more readily than unbelled animals in the open area, and 41 times more readily in the dense brush area. The bell not only aids in locating unseen animals, but

[5] Personal communication with H. Nelson Elliot, District Agent, Bureau of Sport Fisheries and Wildlife, U. S. Fish and Wildlife Service, Sacramento, California.

TABLE 1

Comparison of Observational Success on Belled Deer and Unbelled, Ear-tagged Deer in Two Areas Which Were Intensively Observed During the Winter of 1955-56

	Sample size		Lion Point: Percentage of each sample observed	Lion Point: Average number of observations per deer seen	Kinsman Flat: Percentage of each sample observed	Kinsman Flat: Average number of observations per deer seen
Belled	85		86	4.3	78	6.3
Unbelled	30	Seen in presence of belled deer*	47	3.0	25	3.5
		Seen alone	13	2.1	12	1.0
Observational efficiency Ear-tagged : belled			1 : 14		1 : 11	

* This group is excluded from the calculations to compare observational efficiencies.

makes individual sight recognition easier because it affords greater surface for identifying colors and designs than does the ear tag.

The advantage of bells over ear tags alone in locating deer is even higher when reports are solicited from the public. After the herd had migrated to its 800-square mile summer range following the first winter's trapping, 94 location reports were received. None of these reports identified belled deer to the individual. However, they are valuable in locating the herd as a unit. Practically no reports would be received if the deer were merely ear-tagged.

Techniques

A few methods which improved the success of locating and observing belled deer are given below. Even when resting, a deer usually moves often enough to sound a bell at least once every 25 minutes. Consequently, by moving slowly and stopping frequently, an observer's chance of hearing any one bell in the vicinity is good. When approaching a bell heard in a continuous stand of brush, the observer should avoid flushing the deer before seeing it. Therefore, because the direction and distance of bell sounds are deceptive, and because other deer, acting as sentinels, may be nearby, the approach should be cautious and should be interspersed by frequent peering with binoculars into the brush. When a belled deer is heard from dense brush which is surrounded by open ground, it may be easier to flush the animal into the open for observation.

Interpreting patterns of bell ringing is helpful: e.g., medium volume, steady ringing for grazing; medium volume, irregular ringing and changing direction of source for walking; heavy volume, irregular ringing, and changing direction for running. After estimating direction, an observer can maneuver to a vantage point to intercept a moving deer. A momentary sharp ringing, ceasing abruptly, indicates alarm. In several cases of deer becoming alarmed, a concealed observer, by ringing a bell, calmed the animals into resuming previous activities, after which the observer was able to approach more easily.

Belled deer are especially suited for night location and observation where cover is relatively open. An observer, guided by a ringing bell, can approach to within 25 yards of the deer, then identify it with the use of a light. A sealed-beam searchlight and a pair of binoculars mounted on a gunstock provided a device which was used successfully for identifying individuals at night.

Uses for Study

The location at which a belled deer is seen may be plotted on a map to determine the extent of its range. Belled deer in flight can be followed by an observer; this method, besides providing additional chances to identify the animal if the first attempt is unsuccessful, can be used to plot the flight course. It has been hypothesized that such a course might describe the limits of the area with which the animal is familiar.

Calculation of the Lincoln Index may be made from ratios of marked to unmarked deer only when observation is in no way influenced by bell sounds. Applied to kill returns on belled deer, use of the Lincoln Index is of questionable value because, as was implied earlier, the probability of a belled deer being shot and reported might be decidedly different from that for an unbelled deer.

Belled deer need only to be heard for an observer to know their location and activity. Data of this sort are useful in such studies as deer responses to environmental factors, day or night.

SUMMARY

During the winters of 1955-56 and 1956-57, on a winter range northwest of the San Joaquin River in California, 260 deer were belled and marked for individual recognition. Deer adjusted to the belling with no apparent effect on their condition or behavior. The danger exists that a deer may put its foreleg inside the strap or chain holding the bell if excessive slack is allowed. A weak link or nonpermanent holding device should be used if slack must be allowed for growth. Belling of deer increased subsequent location and individual identification success as much as 41 times over marking only with ear tags. Deer so marked may be located in heavy brush, can be followed when in flight, and can be studied by their sounds even when not visible. On the other hand, using belled deer in Lincoln Index calculations may give invalid results because of the biasing effect of bells on observers or hunters.

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RELATION OF THE ADRENAL CORTEX TO CONDITION OF DEER[1]

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INTRODUCTION

This report presents the results of an investigation into the interactions between the adrenal glands and the condition of deer. The study was inspired by Christian's hypothesis (1950) that Selye's adaptation syndrome may provide an answer to the cause of death in heretofore inadequately explained extensive population die-offs. Death during a cyclic crash has been determined to be caused in some animals by a hypoglycemia with convulsive seizure termed "shock disease" (Green and Larson, 1938; and others).

Frank (1953) has demonstrated that the above-mentioned crash die-off symptoms correlate well in the laboratory with those observed in the field. He found the cause to be depletion of the adreno-pituitary system, brought about by stresses of crowding, and triggered by some environmental factor.

It is generally accepted that adrenal hypertrophy and hyperplasia are reactions of the body to stress (Selye, 1950) and, further, that an increase in adrenal cortical tissue has direct relation to adrenal weight (Hartman and Brownell, 1949; Christian, 1955). Christian and Davis (1955) have shown that in free-living populations of Norway rats there is a decrease in adrenal weight when the stresses of crowding are reduced by reducing the population. They also suggest that animals in populations held at approximately 50 percent of carrying capacity will maintain satisfactory conditions with relation to their environment and possibly avoid cyclic fluctuations.

In order to stimulate further investigations, it was the purpose of this study to determine the morphological picture of the deer adrenal, to analyze the variation which might be expected within a population sample, and to examine various adrenal measurements with relation to condition.

ACKNOWLEDGMENTS

The authors extend their thanks for the time and effort spent by the staff members of Humboldt State College who made this project possible, in particular, Raymond F. Dasmann, under whose direction the work was carried out, and Ernest O. Salo, who assisted in the statistical analysis.

Acknowledgment is given to Jack Hiehle and Ernest Hodson of the California Department of Fish and Game, who made the field collection possible.

[1] Submitted for publication October, 1957.

METHODS AND PROCEDURES

The material analyzed in this study was collected near Paskenta, California, from the Lake Hollow deer herd during a special antlerless deer hunt held in Tehama County November 1-6, 1955. The hunt was held in an area which has long been considered to be overstocked with deer. The population from which the sample was collected was one believed to be in excess of the carrying capacity of the range. The sample was made up of both resident deer from the winter area, which was in poor condition, and migratory deer which had just begun to enter from the comparatively better summer range. It is possible, therefore, that a greater variation in condition was observed than might be expected in a more homogenous sample.

When possible, the following measurements were taken: hog-dressed weight to the nearest pound; length, from the tip of the nose to the base of the tail (to the nearest half-inch); and girth, the greatest diameter posterior to the shoulders (to the nearest half-inch). The deer were aged by examination of the teeth. Pelage color was divided into five classes; red, mostly red and partly blue, red and blue, mostly blue and partly red, and blue.

In order to determine condition, it was hoped originally to use kidney fat weight as described by Riney (1955). This, however, was impractical, due to the conditions of collecting. A substitute method was used, which involved the use of four visually determined kidney fat classes: none, light, medium, and heavy. Adrenals were preserved in 10 percent neutral formalin. After excess fat around the preserved glands had been removed, they were blotted dry and then weighed separately to the nearest hundredth of a gram. After paraffin embedding, medial tranverse sections were prepared at 8μ and stained with Harris hematoxylin and eosin Y.

The average relative widths of the zona glomerulosa, fasciculata, and reticularis of the adrenals were obtained with an ocular micrometer. The sections were then projected onto an opaque glass, from which the relative areas of the cortex and medulla were obtained with a compensating polar planimeter.

Due to the regularity of the width of the cortex and the good correlation between linear cortical measurements and cortical area (p. <0.01), linear measurements were used in the analysis. The medullar cross sections, however, were irregular, necessitating the use of area measurements in computations.

In the following results, only the data gathered from adult ($2\frac{1}{2}$ years or older) female Columbian black-tailed deer (*Odocoileus hemionus columbianus*) were used.

RESULTS

Depletion in amount of body fat deposition in deer is believed to be associated with loss of strength (Leopold *et al.*, 1951; Riney, 1955) and lowering of general condition (Bischoff, 1954). Riney (1955) concluded that kidney fat was the most satisfactory index of fat reserves. The deficiencies in our study resulting from the use of the arbitrary fat determination method are fully realized; however, insofar as the body weight correlations ($p<.05$) are concerned, kidney fat was considered to be the most significant condition factor.

It has been commonly accepted that body weight may be used as a condition factor both in deer and other big game animals (Davenport *et al.*, 1944; Doman and Rasmussen, 1944; Hamerstrom and Camburn, 1950; Leopold *et al.*, 1951; Severinghaus, 1955; and others). If we consider body length to be the most condition-independent body measurement, the lack of correlation between body weight and body length ($p>.05$) suggests that weight should be considered as a condition factor in this sample.

Girth was also examined with relation to condition. Riney (1955) states that girth seems more closely correlated with body size than with the total fat reserve (condition) in red deer (*Cervus elephas*). He further states that in California mule deer (*O.h. californicus*) girth is less desirable than weight as an index to condition, because of its narrow range of variation. In our sample, girth is not correlated with length ($p<.05$), and body weight varies with girth ($p>.05$).

The onset of the fall molt has been another generally accepted deer condition factor. Supposedly, an animal in poor shape will retain its summer red coat longer than one in better condition. A lack of correlation between kidney fat and pelage ($p>.05$) shows that this is not true in our sample.

The lack of correlation between adrenal weight and body length ($p>.05$), coupled with significant negative correlations between both adrenal weight and body weight (negative, $p<.05$) and kidney fat and adrenal weight ($p<.01$), indicates that adrenal weight is a function of condition and not size of the animal. To account for variations in the size of the gland which might be due to body size, adrenal weight/body length and body weight (negative, $p<.05$), and adrenal weight/

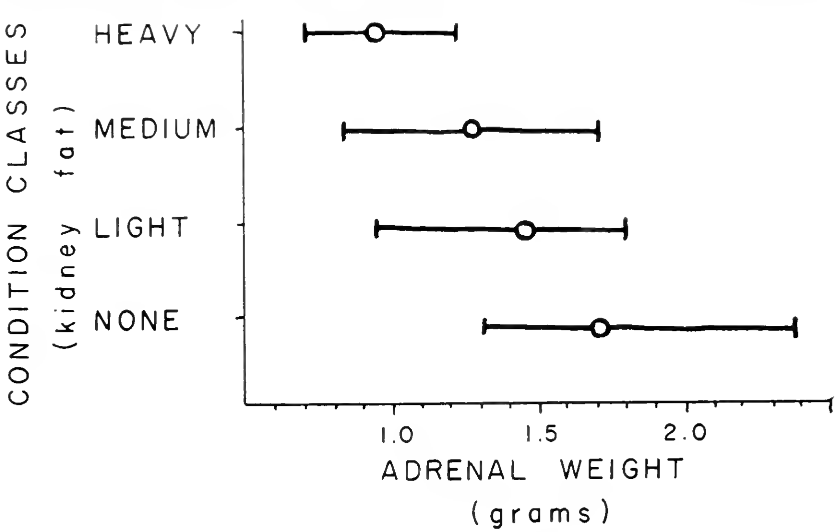

FIGURE 1. The adrenal weights of adult female deer. The weights of the individual glands are plotted as means within condition classes (kidney fat). The range is given for each condition class.

body length and kidney fat (negative, $p<.01$), are similar to those described above. An excellent correlation was obtained by averaging the adrenal weights in each condition class (kidney fat) and plotting them with condition (negative, $p<.01$) (Figure 1, Tables 1, 2).

TABLE 1

Correlations, Correlation Coefficients, and Significance Levels for Deer Within a Population Sample

Condition correlations		N	r	p
Body weight	X Body length	26	0.25	>0.05 n.s.
Girth	X Body length	25	0.14	>0.05 n.s.
Girth	X Body weight	26	0.42	<0.05
Body weight	X Kidney fat	22	0.52	<0.05
Pelage	X Kidney fat	29	0.13	>0.05 n.s.
Adrenal weight—Condition correlations				
Adrenal weight	X Body length	33	0.232	>0.05 n.s.
Adrenal weight	X Kidney fat	27	−0.57	<0.01
Adrenal weight/Body length	X Kidney fat	27	−0.57	<0.01
Adrenal weight (Av. in cond. class)	X Kidney fat	4	−0.97	<0.01
Adrenal weight	X Body weight	33	−0.41	<0.05
Adrenal weight/Body length	X Body weight	32	−0.46	<0.05
Adrenal weight	X Girth	33	−0.32	<0.06 n.s.
Adrenal cortical and medullar correlations				
Adrenal cortex (linear, in arbitrary units)	X Adrenal cortex (area, in arbitrary units)	21	0.89	<0.01
Adrenal weight	X Adrenal cortex (linear, in arbitrary units)	23	0.67	<0.01
Adrenal weight	X Adrenal medulla (area, in arbitrary units)	18	−0.33	>0.05 n.s.

N = number in sample.
r = coefficient of correlation.
p = level of significance.
n.s. = not significant at 95 percent level.
> = p is greater than.
< = p is less than.

TABLE 2

Summary of Measurements of Adult Female Deer From the Lake Hollow Herd

	Sample	Mean	Maximum	Minimum	Standard deviation
Length (cm.)	33	128.0	160.0	109.2	23.8
Weight (kilog.)	33	26.3	34.9	19.9	3.4
Girth (cm.)	33	25.6	88.9	66.0	5.1
Adrenal weight (gm.)	33	1.45	2.36	0.69	1.21
Cortex (linear, arbitrary units)	21	2.68	4.0	1.80	0.59
Medulla (area in arbitrary units)	16	4.51	6.3	3.10	1.51

Adrenal weight might also be expected to vary with girth; however, the correlation is below the 95 percent level of significance ($p<.06$).

Adrenal hypertrophy and hyperplasia occur in the adrenal cortex during resistance to stress. The medulla is not affected by stressors in this manner (Selye, 1950). Cortical enlargement in this study could not be attributed to any particular zone.

Due to the correlation between adrenal weight and cortical width ($p<.01$) and lack of correlation between adrenal weight and medullary area (negative, $p>.05$), it is believed by the authors that the variations in adrenal weight are a reflection of the adaption of the deer to stress.

SUMMARY AND CONCLUSIONS

It was surmised originally that a sample of a restricted population of deer would show uniform condition. The results could then be used for comparison with other populations. The actual variations observed in condition factors (primarily body weight and kidney fat), however, lead to a contrary hypothesis; namely, that there was a significant difference among individuals in the sample. The onset of the fall molt seemed to have no correlation with condition in this sample.

The lack of correlation between these condition factors and body length (here assumed to be the most valid, condition-independent body measurement) added emphasis to the latter assumption.

Adrenal hypertrophy and hyperplasia are generally accepted as being a reaction of the body to stressors. The significant negative correlations between the amount of adrenal cortical tissue and the condition factors indicate that Selye's General Adaptation Syndrome was the mechanism affecting these variations in adrenal size.

It is concluded that in the deer sampled adrenal cortical size, most easily measured as adrenal weight, may be considered as a condition factor with regard to the field condition determinants presently in use.

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RESIGNATION

WILLIAM P. DASMANN

William P. Dasmann, Game Management Supervisor in charge of big game, resigned from the California Department of Fish and Game on January 10, 1958, to accept the position of Wildlife Management Supervisor for the United States Forest Service, California Region.

Bill joined the Department (then Division of Fish and Game) as a range technician in September of 1946. Except for a brief period as assistant to the Chief of the Game Management Branch, his field of activity has been big game research and management.

Bill was ably prepared for his job. Prior to government service he had spent some time working on cattle ranches. He was graduated from the University of California with a degree in forestry and range management. Before coming to the State, he was employed as a range examiner and district forest ranger by the United States Forest Service.

Bill is an able and hard worker. His numerous writings, both popular and technical, have brought him nationwide recognition as one of the top men in the deer management field.

Deer management is a controversial subject, particularly in California. It is a tribute to his personality that individuals who disagreed with him most vigorously liked him on personal contact.

His various friends and associates in the Department will certainly miss him. However, they are looking forward to many more years of pleasant association with him in his new job.

His friends in the Department extend to Bill best wishes for success and happiness in his new endeavor.—*C. M. Ferrel, Game Management Supervisor, California Department of Fish and Game.*

REVIEWS

Sea Fisheries: Their Investigation in the United Kingdom

Edited by Michael Graham; Edward Arnold (Publishers) Ltd., London, 1956; xii + 487 p., illus. $25.

Mr. Graham and those associated with him in the production of this book are much too modest when they indicate that this volume is intended to be "readable to anyone who is sufficiently interested, without special training in science or in fisheries".

It is apparent that "Sea Fisheries" answers the requirement for a comprehensive work dealing with all facets of marine fisheries research. In this respect, this volume is "readable". But, in the opinion of this reviewer, only trained fisheries workers will be able to visualize the full import of the material presented. Even these workers will find that by rereading many times they will discover new avenues of approach to marine fisheries problems. Nevertheless, it is recommended that this book be read by the person with a casual interest. It is certain to open the eyes of even those who prefer to operate from day to day with only the minimum of understanding.

A brief review of each chapter will serve to show something of the scope of this book.

Chapter I—Science and the British Fisheries, by Michael Graham.

Traces the origin of the science, emphasizing the work of several pioneers.

Chapter II—Fisheries of the United Kingdom, by Henry Wood.

We find that two distinct groups of fishes inhabit the sea; one group is related to the ocean bottom, the second to the water body (pelagic). The gear used to harvest each of the two groups of fishes assumes a characteristic form. The author states that, scientifically speaking, controlled fishing has been the management tool for the bottom fisheries, while in the pelagic fishery scientific emphasis has taken the form of prediction and technical aid to the industry. The outlook for the future is somewhat sombre for the demersal fisheries, but production is capable of a higher return for pelagic fisheries.

Chapter III—Plankton and Basic Production, by C. E. Lucas.

There are two broad classes of plankton; plants and animals. Plants utilize basic nutrients and carbon dioxide in combination with chlorophyll to produce vegetative mass. The animals of the plankton utilize the vegetative production and are in turn preyed upon by other animals. Special research techniques are described.

Chapter IV—Plankton and Fisheries Biology, by C. E. Lucas.

An understanding of the relationship of plankton to the fisheries is shown to be on the increase. It is pointed out that benthic animals, upon which demersal fishes largely depend, are direct consumers of the plankton body. Pelagic fishes feed directly upon plankton. Certain plankton species can serve as biological indicators of typed water masses. Knowledge of abundance and kind of plankton may be useful in the prediction of fisheries. It may be possible to increase plankton production by fertilization, thereby producing new fisheries or enhancing existing ones.

Chapter V—Benthos and the Shellfish of Commerce, by H. A. Cole.

Benthos, or bottom life, is predominantly animal. Benthic plants occur where shallow waters allow sufficient light to filter through. Some shellfish, such as oysters, lend themselves to cultivation, while for others man lacks enough basic biological knowledge to permit cultivating. Protective aid, the present management tool, can be more effective with lobsters and crabs when basic biology is better understood.

Chapter VI—The Pelagic Phase, by A. C. Simpson.

Eggs and larvae of fishes are pelagic, with a few exceptions. The pelagic phase is shown to be highly important in the distribution of species and the volume of eggs and larvae as determined in plankton collections is an indicator of the extent and size of spawning stock. The association between wind and the strength of year classes of fish from year to year needs to be resolved.

Chapter VII—The Cod, Haddock, and Hake, by B. B. Parrish.

The author discusses the data needed for a demersal fishery in order to solve the question of overfishing. Commercial statistics, knowledge of recruitment, growth, fishing, and natural mortality are basic requirements. A program for research is outlined. A discussion of the stocks of cod, haddock, and hake illustrate the variety of conditions encountered in the study of such stocks.

Chapter VIII—Plaice, by Michael Graham.

This chapter traces the undisputed factors of life relating to the plaice. A discussion of plaice stocks, eggs and young, and age groups is included in the chapter. Marking of plaice is highly successful. Transplantation of plaice from overcrowded conditions to new and lightly inhabited areas has been tried with success.

Chapter IX—The Theory of Fishing, by R. J. H. Bererton and S. J. Holt.

The solution to the problem of regulating the demersal fisheries lies in tying information on recruitment, growth, natural mortality, and fishing together, since they operate simultaneously. Equations for handling these factors are introduced. Previous chapters revealed by example how the answers to these vital questions can be determined.

There is litle doubt that this publication will become one of the most important references in the field of modern fishery science. The authors should be highly commended for their contributions.—*Parke H. Young, California Department of Fish and Game.*

The Physiology of the Pituitary Gland of Fishes

By Grace E. Pickford and James W. Atz; New York Zoological Society, New York, 1957; 637 p., incl. 54 tables, $6.

Admittedly this book will be well received by those working in the field of fish endocrinology. Additionally, it should bring heel clicks of joy from fishery biologists and fish culturists faced with the problem of influencing the spawning time of fish.

Runs of anadromous salmonids face extinction in some of our west coast streams because of dam construction. Their salvation may very well rest on accelerating the spawning time of long-run and perhaps even spring-run fish.

The Physiology of the Pituitary Gland of Fishes is divided into a text, tables (some 200 pages), and a bibliography.

The proposed terminology in the introductory chapter clearly indicates the different regions of the fish pituitary, and also provides background information on mammalian cell types and hormones.

The section on the pituitary hormones of fishes is prefaced by information on the hormone in amphibians, birds, and mammals. Then the classes, orders, and suborders are dealt with and provide an excellent contribution to this facet of the book.

The section dealing with the pituitary and reproduction has resulted in an excellent assembling of the scattered and almost unavailable literature (Russian and Brazilian). Methods of treating fishes with hormones to induce spawning in captivity are described in detail.

The tabulated data are presented in an admirable form and at what must have been quite an effort on the part of the authors; all known experiments to June, 1956, dealing with the pituitary and its physiology have been included. The combined Bibliography and Author Index is up to date and inclusive and contributes to the value of this book.

The well-organized and comprehensive manner in which this book has been developed will make it a "must" on the shelf of those interested in endocrinology, physiology, fishery biology, or fish culture.—*Harold Wolf, California Department of Fish and Game.*

Sea Angler's Fishes of New Zealand

By Arthur W. Parrott; Hodder and Stoughton, London, 1957; 176 p., color frontispiece, 12 plates, 56 figures, 18 shillings.

The 56 species of New Zealand's marine fishes described and illustrated herein are those the author regards as most likely to be caught by sport and commercial fishermen—exclusive of big game fishes, flatfishes, and eels, which Mr. Parrott proposes to make the subject of later volumes. Language and style are aimed at the lay reader. He should find the book most useful; the professional will regard it with a dimmer view—but it is not meant for him. Each species is described in what appears sufficient detail for the purpose; there follows, so far as known or appropriate, its distribution, its life history, its importance, angling hints, how to prepare it for the table, and miscellaneous bits of information. A glossary and illustrations of external anatomy cover those technical terms which are used. Average and maximum weights and lengths appear in a table. Confusion in common names appears as much a problem in New Zealand as any place else and Mr. Parrott makes a plea for standard usage, followed by a list including scientific, recommended common, and other common names. May he have more success than have some of the others of us who have wrestled with the problem of vernaculars. *Phil M. Roedel, California Department of Fish and Game.*

Handbook of Snakes of the United States and Canada

By Albert Hazen Wright and Anna Allen Wright; Comstock Publishing Associates, Ithaca, N. Y., 1957; 1,133 p., 306 figs., and 70 maps. $14.75.

In these two volumes the Cornell University Press, through its Comstock Publishing Associates division, has brought out another classic to stand beside the long familiar *Handbook of Frogs and Toads of the United States and Canada*. Although the book is full of interest for the inquiring layman, it is intended primarily for the serious student of herpetology. It is, therefore, no easy short-cut guide for the identification of the approximately 300 species and subspecies described.

It is difficult to avoid comparing this work constantly with the *Handbook of Frogs and Toads*. Like that volume, it is noteworthy for its wealth of excellent photographs and distributional maps as well as its highly accurate, illustrated keys. To this reviewer, one of the most interesting features is the inclusion of many of Dr. Wright's personal field notes, which bring to life the exciting search for snakes in all parts of the country. These notes are also a good example of the later importance of what seems temporarily of little significance. They should serve as a valuable guide for the beginning herpetologist. Credit is given freely to everyone who helped the Wrights in the field and one wonders how such busy people could have found time to make so many contacts.

In the introductory section of the book the Wrights cover names of snakes (including among other items, English equivalents of Latin names, present classification, problematical species, and Mexican border species), range, size (of adults), longevity, distinctive characteristics, color, habitat, period of activity, breeding, ecdysis, food, venom and bite, enemies, and field notes. The same system is followed under each species and subspecies whenever applicable. The result is an excellent summary of the ecology of the various snakes. If there is any criticism of the book, it is the lack of any explanation of the field methods employed in the study of snakes, such as is contained in the 77-page introduction to Schmidt and Davis' *Field Book of Snakes* (1941). The ideal would perhaps be a consolidation of the introductions and instructions from each of the two books, for they supplement each other admirably.

Volume I does not contain an index but the index for both volumes is at the end of Volume II. The book is well documented under the heading following the description of each species or subspecies, although here only dates and authors' names appear in most cases. This is because there is in preparation a third volume, which will be a bibliography containing three sections: a general list, an ecological list, and state lists, each arranged chronologically. It is unfortunate that all three volumes did not appear simultaneously.

Although it would seem that there was little room for another snake book among the many beautifully prepared volumes already available, there is little doubt that this contribution is outstanding in its authoritative and comprehensive coverage. It cannot be recommended too highly.—*Herbert E. Pintler, California Department of Fish and Game.*

Water for America: The Story of Water Conservation

By Edward Graham and William Van Dersal; Oxford University Press, New York, 1956; 112 p., 53 black-and-white photographs. $3.50.

It has often been said that the greater knowledge a man has, the better he is able to explain a subject in a simple, understandable manner. On this basis, authors Graham and Van Dersal qualify as experts in their field. They have been able, through the use of relatively few words and a fine series of photographs, to give full coverage to the important elementary principles and concepts of water conservation in America.

The book's effectiveness is greatly influenced by its organization. Each right-hand page covers an individual topic such a rain, irrigation, water for wildlife, etc., while the left page opposite graphically illustrates, through full-page photographs, the subject under discussion.

This cannot be termed a book for the water conservation technician, even though a surprising amount of factual information is packed into relatively few pages. However, it is especially well adapted for school use and all those desiring a basic understanding of present-day water problems.—*Willis A. Evans, California Department of Fish and Game.*

A Flora of the Marshes of California

By Herbert L. Mason; University of California Press, Berkeley, 1957; x + 878 p., 367 figs. $10.

Among California's botanists and wildlife people, especially those in waterfowl work, a topic of conversation for a number of years has been: When will Dr. Mason publish the results of his work on the marsh flora of California?

The background to this study involved a Pittman-Robertson federal aid project initiated in 1945 and terminated in 1951. This was a contractual project between the California Department of Fish and Game and the University of California at Berkeley, entitled "A Survey of the Waterfowl Food Plants of California", whose objective was a state-wide survey of the marsh floras of California. A critical need for an illustrated reference text on western wetland flora was recognized. Available texts, such as Muenscher's "Aquatic Plants of the United States" and Fassett's "Manual of Aquatic Plants", had proved inadequate for individuals involved in Californian marsh ecology, not only those in the academic fields, but also—and especially—wildlife workers engaged in waterfowl habitat management and research.

The results of the extensive research of that project are now available. For the everyday botanist, this book resolves much of the confusion he has met in attempting to keep abreast of the taxonomic changes in the groups in which he does not specialize. A botanist is often confronted with the frustration of speciation. For example, "alkali bulrush" is an important duck food. Abrams gives it as *Scirpus paludosus* Nels. 1899, Jepson found it proper to call it *Scirpus campestris* Britt. 1896, and Mason now defines the plant as *Scirpus robustus* Pursh. 1814. Thus, the *S. robustus* of the brackish and saline marshes of the East coast is synonymous with the western *S. paludosus*. Only when one realizes that each species of plant discussed in this volume necessitated not only extensive field work but also many tedious hours of literature search and confirmation, can he be appreciative of the immense amount of time involved in the preparation of this valuable text.

The identification of an unknown plant specimen generally follows the procedure of keying the plant to a family and then determining the genus and species from the descriptions given. Dr. Mason's introductory General Key to the Families projects one into the pages following and subjects him to a pleasant surprise. The keys to and descriptions of the plant genera and species, plus the geographical and ecological ranges for all species, give to even the most inexperienced person the satisfaction of being able to identify his unknown plant or getting tolerably close to it. Many of us "picture book" botanists, who rely heavily on pictures to identify a plant (there are few botanists who don't), will find the illustrations in this text to be second to none. The artists responsible are to be commended for their superb work. The pictures drawn from fresh specimens are not only exact replicas, but also include the morphological characteristics used to distinguish the species, which are so ably pointed out in the footnotes accompanying each plate.

This book is a good ten-dollar investment for anyone interested in waterfowl and waterfowl habitat. It should resolve a lot of confusion and difficulty in communications among waterfowl workers. Whether a person be a marsh ecologist, a waterfowl food habits biologist, a game manager developing a waterfowl management area, or a duck club owner hopeful of improving his club, all have a common interest—the perpetuation of waterfowl and the wetland habitat that supports this resource—and this book can be of valuable assistance.—*Howard R. Leach, California Department of Fish and Game.*

California Range Land

By L. T. Burcham; Calif. Div. of Forestry, Sacramento, 1957; 261 p., illus. $3.

At the time of the arrival of the "Anglo-Americans" in California, the livestock industry had already been established for nearly three-quarters of a century. Native perennial grasses had been largely replaced with annual native and introduced plants, from the Mediterranean in the most part. However, although Burcham considers perennials to have been dominant in the pristine Central Valley, he is certain that in some areas the annuals made up the greater part of the cover composition. A study of the bibliography discloses the scope of detection required of the author in order to piece together the bits of information about California's early rangelands. This work in itself would have furnished sufficient reason for publication.

The trend in livestock kinds and numbers is traced from 1850 to the present and is broken down to individual counties. It is pointed out that the average live weight of stock on the ranges increased about 25 percent during the last century; that fact alone depicts the continually increasing demands on the range resources.

The last quarter century has shown a reversal of the downward trend of the range. The development of range evaluation techniques, proper grazing techniques, and range improvement have furnished the tools for further improving the range.

Burcham has not neglected wild species in his evaluaton of the rangelands. The only drawback is that elk, deer, and antelope are not indexed; a search of the text is needed to learn, for example, that "The pronghorned antelope was the most important game animal".

Despite this shortcoming, this book should be in the library of every person concerned with Californa ranges, whether that concern be big game or livestock.—*Henry A. Hjersman, California Department of Fish and Game.*

The Pacific Coastal Wildlife Region: Its Common Wild Animals and Plants

By Charles Yocom and Raymond Dasmann; Naturegraph Company, San Martin, California, 1957; 112 p., illus. Paperbound $2, clothbound $3.

This is a handbook of the commoner plants and animals occurring in the moist belt along the coasts of Washington, Oregon, and northern California. It is intended primarily to aid in their identification. The first half describes about 100 plants, grouped by six "habitat types", also described and illustrated. There are ink sketches of about two-thirds of the plants. The second half of the book describes about 50 mammals and 100 birds. They are arranged taxonomically, with cross references to habitat types. Most of the animals are illustrated by ink sketches. Reptiles and amphibia are also treated briefly but well. The material is appropriately and pleasingly handled for all groups except fish, which are dealt with so incompletely that they could better have been omitted.

Grade-school teachers, beginning students, and other nonspecialists will find this book helpful in identifying the plants and animals they encounter along the coast. They should also enjoy the general information it contains about these forms and their environments.

Much of the book's charm stems from an extremely generous peppering of its pages with pen-and-ink sketches: two or more on nearly every page. Most of them capture the character of the species in pleasing, life-like representations. Fish, again, are a notable exception.—*Alex Calhoun, California Department of Fish and Game.*

How to Know the Freshwater Fishes

By Samuel Eddy; Wm. C. Brown Company, Dubuque, Iowa, 1957; vi + 254 p., illus. Spiralbound $2.75, clothbound $3.25.

This book is another in the very useful visual series edited by H. E. Jaques. Dr. Samuel Eddy, the author, is a professor of zoology at the University of Minnesota. He is a well-known authority on fishes, with many publications in the field of ichthyology, including the coauthored (with Thaddeus Surber) *Northern Fishes.*

The key has been made as simple as possible. For the most part, unnecessary technical terms have been avoided. Two brief and useful introductory sections concerning interesting facts and pertinent fish anatomy are included.

A series of indigenous California species was keyed out by this reviewer with ease. Several genera (e.g., *Siphateles*) are not carried out to species. This is understandable, since the position of numerous subspecies is not clear. The myriad members of the genus *Notropis* all appear to have been included. The only California representative, *Notropis lutrensis*, keyed out quite easily.

Nearly all of the California indigenous minnows seem to have been illustrated from preserved, frequently immature, specimens or from illustrations. The result is that few of them accurately represent the species they mean to illustrate. A number of errors in ranges were also noted (e.g., threadfin shad, page 43). The common name of *Chasmistes cujus* is given as Couis, rather than Cui-ui. Nearly all the omissions noted by this reviewer may be attributed to a first edition or to the eastern affiliations of the author.

We have waited for a long time for a key to the freshwater fishes of North America. Despite the remarks in paragraph three above, the book is well worth the moderate asking price.—*J. B. Kimsey, California Department of Fish and Game.*

The Fishes of Ohio

By Milton B. Trautman; The Ohio State Univerity Press, Columbus, 1957; xviii + 684 p., 172 figs., 172 maps, and 7 color plates. $6.50.

Milton B. Trautman is curator of vertebrate collections at Ohio State University. He has studied the fishes of Ohio for more than 25 years. This book is the result of (1) an intensive review of the literature relating to Ohio fishes and the Ohioana, undertaken during the 1925-53 period, (2) examination of approximately 150,000 preserved specimens that were collected between 1860 and 1950 in Ohio waters, and (3) Dr. Trautman's extensive knowledge of the state and its fish fauna.

There can be little doubt that it is "the" book on Ohio fishes. There is a chapter on Ohio geography, one on the changes in ecological conditions between 1750 and 1800, and a helpful interpretation of scientific names, listing changes that have occurred in them in the past. As you might expect in a book describing 160 species and 12 subspecies of fishes, the keys to identification take up some room (50 pages). These keys are clear and readable. They are made more so by 15 pages of descriptions of terms, measurements, etc., telling how to use them in identifying "your" fish. The remaining pages are used to describe each species separately. Some taxonomists may not agree with the validity of Dr. Trautman's subspecies. Most of us can easily allow him 12 subspecies in return for the fine descriptions of the 160 species. For each there is a drawing of the adult, often with inserted drawings that show in detail features which are important to identification. There is often a drawing of the young. These drawings were made from carefully selected preserved specimens, from which measurements were transcribed to the paper with proportional dividers. They are more than drawings: they are plans of fish, and probably are the most accurate ones available.

The text describing each species includes a description of adult characteristics, a short list of other fishes that might be confused with the specimen in hand, and usually some information on the best way to tell the confusing species apart. Colors of both adult and young are described. There is usually some brief information on the growth and maximum lengths and weights attained.

There is a short section on Ohio distribution and habitat of each fish. Most Californians will care little about the distribution of fish in Ohio. Dr. Trautman has, however, turned this into something that is of interest to us. He has written the history of each species, outlining as closely as possible the ways in which its distribution and abundance was affected by the civilization of the state. This will be a most significant part of the book for Californians. It is a documented story of the permanent destruction of great populations of desirable stream fishes by changes in the habitat. These changes occurred between 50 and 150 years ago in Ohio and were caused mainly by pollution, soil erosion, and the construction of dams that blocked migration. These are the problems we face today, and all persons interested in preserving our resources should read Dr. Trautman's chapter on the destruction of his.

No review would be complete without mentioning the clarity with which Dr. Trautman writes. He writes in the first person singular. He does not refer to "the present author" but says simply, "I". When talking of Ohio fishes, there is no one more qualified to use that pronoun.—*D. W. Kelley, California Department of Fish and Game.*

The Physiology of Fishes. Volume 2: Behovior

Edited by Margaret E. Brown, Academic Press Inc., New York, 1957; xii + 526 p., illus. $14.

Volume 1, *Metabolism*, of *The Physiology of Fishes*, seemed to have disturbed certain members of the fisheries profession in this Country, who perceived a relationship between it and the current national crisis. It seems that only one of the 10 authors of Volume 1 is from the United States. At the time this publication reached the bookstores, two "sputniks" were already orbiting and stirring tremendous interest in science and education. Our lag in the field of space travel was attributed to neglect of basic research. This neglect, the fisheries people contended, was also reflected in our lack of contributions to this important book. Alas! we have weathered the crisis. Our "Explorer" has taken its place among the "sputniks" and, of the 14 authors contributing to Volume 2, seven are from the United States.

The 14 authors of Volume 2, *Behavior*, are as outstanding in their respective specialties as those who contributed to Volume 1, *Metabolism*. For example, you will find *Physiological Genetics of Fishes* by Myron Gordon, *Olfactory and Gustatory Senses of Fishes* by Arthur D. Hasler, *The Ethological Analysis of Fish Behavior* by G. P. Baerends, and *Water Quality Requirements of Fishes and Effects of Toxic Substances* by Peter Doudoroff. These were chosen at random; the remainder have achieved similar stature in their fields.

This is not a textbook. It is a reference book in the finest sense—an invaluable aid to the fisheries scientist, general zoologist, comparative physiologist, and advanced college student. Each author presents a detailed discussion of his subject. In addition, there are many descriptions of experimental procedures and equipment. The diagrams, graphs, and photographs are sufficient in number and have been chosen with great care. They are clean-cut and understandable. Many are new, giving the book a refreshing quality not found in other works employing the same old, tired figures. A comprehensive and carefully selected bibliography attends each subject; these bibliographies alone are worth the price of the book. This book meets the basic requirement of a good reference work—that of making information easy to find. It contains not only excellent and separate author and subject indexes, but each subject is prefaced by a detailed table of contents.

It is difficult to find major defects in a work of this type. A total of 24 scientists (for both volumes), each writing about his own particular phase of fish physiology, cannot provide a complete and impartial coverage of the subject. Someone's pet interest is certain to be slighted to some extent. For example, another reviewer has stated that there is insufficient histology in the first volume. I was disappointed in the brief treatment of fish nutrition and noticed that the subjects of venomous fishes and fish poisons were not mentioned. This is regrettable but probably unavoidable.

The most serious criticism of the two volumes is the price—$26 for 973 pages of text. This will put them out of range of those who could make best use of them. Library copies are certain to be well thumbed.—*Almo J. Cordone, California Department of Fish and Game.*

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STATE OF CALIFORNIA
FISH AND GAME COMMISSION

Notice is hereby given that the Fish and Game Commission will meet on April 4, 1958, in the State Employment Building, 722 Capitol Avenue, Sacramento, California, to receive recommendations from its own officers and employees, from public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof, in accordance with Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission

Notice is hereby given, in accordance with Section 206 of the Fish and Game Code, that the Fish and Game Commission shall meet on May 30, 1958, in the California State Building, First and Broadway, Los Angeles, to hear and consider any objections to its determinations and proposed orders in relation to birds and mammals for the 1958 hunting season, such determinations and orders resulting from hearing held on April 4, 1958.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission